HYDROLOGIC RECONNAISSANCE OF THE

Chilkat River Basin

SOUTHEAST ALASKA

With Special Reference to the Alaska Chilkat Bald Eagle Preserve

By Edward F. Bugliosi

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1988

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CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units, rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
ton, short, per day (ton/d)	0.9072	megagram per day (Mg/d)
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius (°C)

Other abbreviations in this report are:

    μS/cm, microsiemens per centimeter at 25 °C
    mg/L, milligram per liter
    μg/L, microgram per liter
    NTU, nephelometric turbidity unit

Sea level:

In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929) -- a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

HYDROLOGIC RECONNAISSANCE OF THE CHILKAT RIVER BASIN, SOUTHEAST ALASKA

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ABSTRACT

The Chilkat River basin in southeast Alaska is characterized by rugged, highly dissected mountains with steep-gradient streams, braided rivers in broad alluvium-filled valleys, and numerous glaciers. A wide seasonal range in temperature and strong orographic effects cause variations in the amount and distribution of precipitation, and thus in the resulting runoff and streamflow. Streamflow is lowest in winter, when precipitation at higher altitudes is stored as snow, and greatest in summer, when melting snow and glacier ice augment flow. Ground-water seeps and springs flowing from alluvial fans contribute to streamflow year round.

A ground-water discharge zone of particular interest is that along the toe of the Tsirku River alluvial fan, 20 miles north of Haines. During winter, the relatively warm (4 to 6 degrees Celsius) ground water maintains open leads in a reach of the Chilkat River downstream from the fan. This ice-free reach provides favorable spawning habitat for a late run of chum and coho (silver) salmon, which in turn attracts the world's largest concentration of bald eagles (more than 3,000 birds). The principal source of recharge to the ground-water system in the fan is infiltration from the Tsirku River.

Surface and ground waters are chemically similar, calcium bicarbonate types. All stream samples had dissolved-solids concentrations of less than 115 milligrams per liter; values for ground water were slightly greater. During high summer flows, the suspended-sediment concentrations of the glacially fed Chilkat, Tsirku, and Klehini Rivers ranged from 361 to 1,530 milligrams per liter (6,360 to 22,300 tons per day).

INTRODUCTION

The Chilkat River basin, at the head of Lynn Canal about 80 mi northwest of Juneau in southeast Alaska (fig. 1), is bordered by the Takhinsha Mountains and Glacier Bay National Park and Preserve to the south and by the Takshanuk Mountains to the east (fig. 2). The northern and western parts of the basin lie within British Columbia, Canada.

The area around the toe of the alluvial fan at the mouth of the Tsirku River, which enters the Chilkat River near the community of Klukwan, is the site of the largest known concentration of bald eagles in the world (Boeker and others, 1980) and has been designated the Alaska Chilkat Bald Eagle Preserve. As many as 3,000 eagles are attracted each year by the late-fall to early-winter runs of chum and coho (silver) salmon up the Chilkat River. The spawned-out salmon provide the

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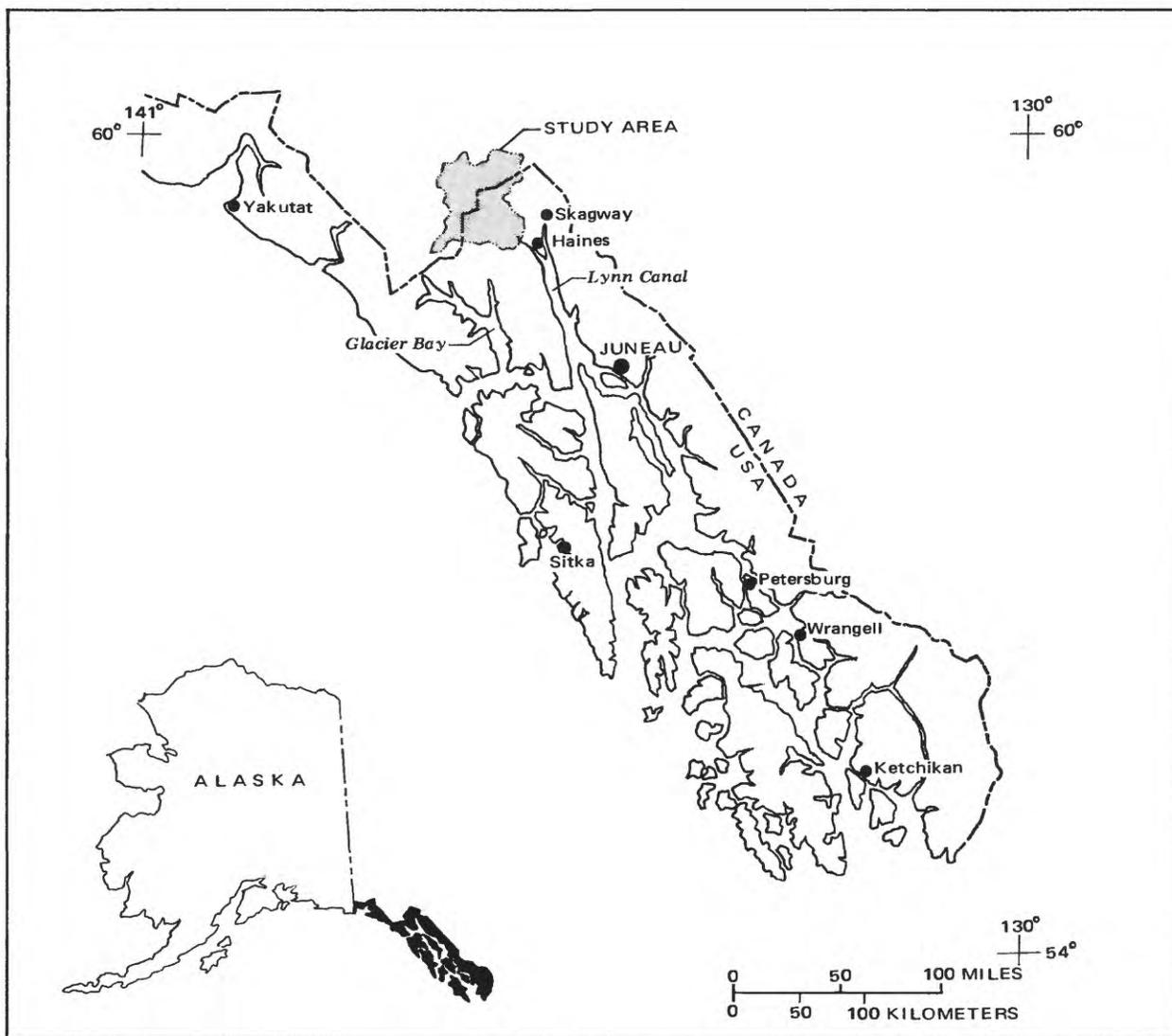
Figure 1. -- Location of study area.

birds with an abundant food source during the winter months because much of the Chilkat River at the toe of the Tsirku River fan remains free of ice.

Hydrologic investigations were begun in the Chilkat-Tsirku Rivers area by D.M. Bishop (1980) in response to concerns of State and Federal wildlife agencies and the National Audubon Society that potential mining and logging activities in the area might affect the hydrologic system and consequently the salmon-eagle relationship. The U.S. Geological Survey began its hydrologic study of the area in May 1981 under a cooperative funding agreement with the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys (DGGS). The DGGS also drilled the water-level observation wells on the Tsirku River alluvial fan, and continues to share costs with Geological Survey to operate the stream-gaging station established on the Klehini River as part of the study.

2

——————·· ——————— Drainage basin boundary
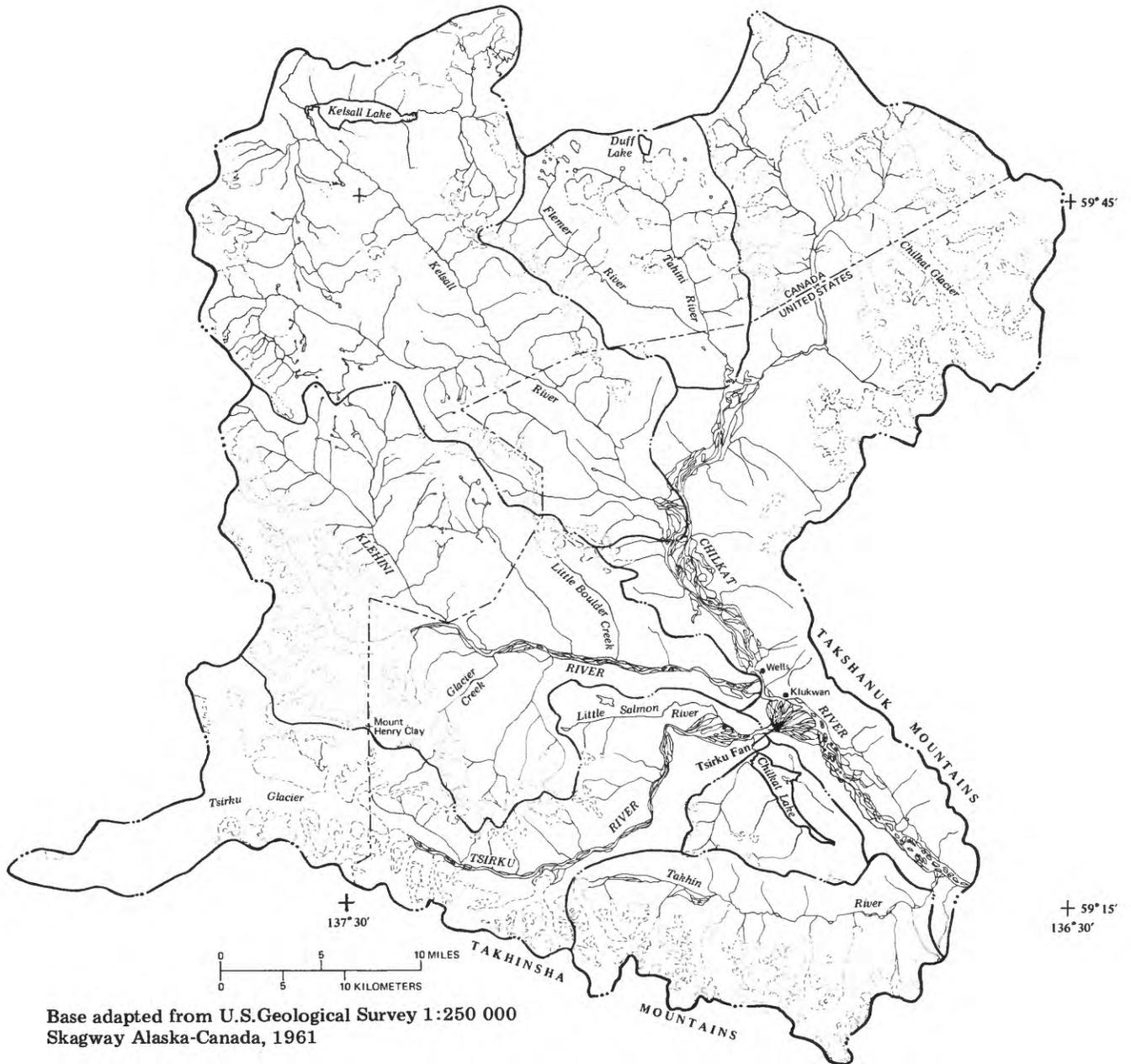
Figure 2. -- Chilkat River basin, major subbasins, and locations mentioned in text.

Purpose and Scope

The objectives of this study were to (1) describe the general geology and hydrology of the Chilkat River basin, and (2) determine the relation between surface water and the ground water in the vicinity of the Tsirku River alluvial fan. The information compiled and data collected as part of the study are presented and discussed in this report.

Acknowledgements

The author wishes to thank Larry Dearborn (then hydrologist with DGGS) for geophysical logging of the observation wells, and for his suggestions regarding the hydrogeology of the study area. Dearborn and DGGS hydrologist James Munter also provided technical review of an early draft of this report. Thanks are also due the people of Haines and the Chilkat River valley for their cooperation and assistance in the conduct of the study. I also wish to acknowledge the cooperation of, and information from, the staff of the National Audubon Society in Alaska.

Physiography

The Chilkat River basin (about 1,000 mi^2), is characterized by rugged, highly dissected mountains with steep-gradient streams; braided rivers in broad, glaciated, U-shaped valleys; and numerous glaciers (fig. 2). Altitudes range from sea level at the mouth of Chilkat River to 7,434 ft at the summit of Mount Henry Clay. Areas below timberline (about 2,000 ft altitude) support dense brush and forests of spruce and hemlock.

Climate

The climate is typified by moderate summers and moderately mild winters with heavy snowfall. Weather conditions, especially precipitation, change within short distances owing to local orographic, glacial, and oceanic effects. Mean annual precipitation at Haines is 65 in., compared with 20 in. at Klukwan. Mean annual temperature also decreases from 40 to 36 °F between Haines and Klukwan (Johnson and Twenhofel, 1953).

During the period May 1982 to June 1983, the temperature at Haines ranged from -12 to 92 °F. It is not uncommon for simultaneous temperatures to differ by as much as 10 °F between Haines and Klukwan, 20 mi from each other. Precipitation also differs significantly between the two areas (fig. 3). Generally, during winter, the Tsirku alluvial fan area near Klukwan is colder and receives less precipitation than Haines.

GEOLOGY

The Chilkat River basin is divided into two distinct geologic provinces by the Chilkat River fault (which roughly parallels the Chilkat River), an extension of the Chatham Strait fault system to the south (Brew and others, 1966; Ovenshine and Brew, 1972). The geology of two 1:63,360 quadrangles (Skagway B-3 and B-4) has
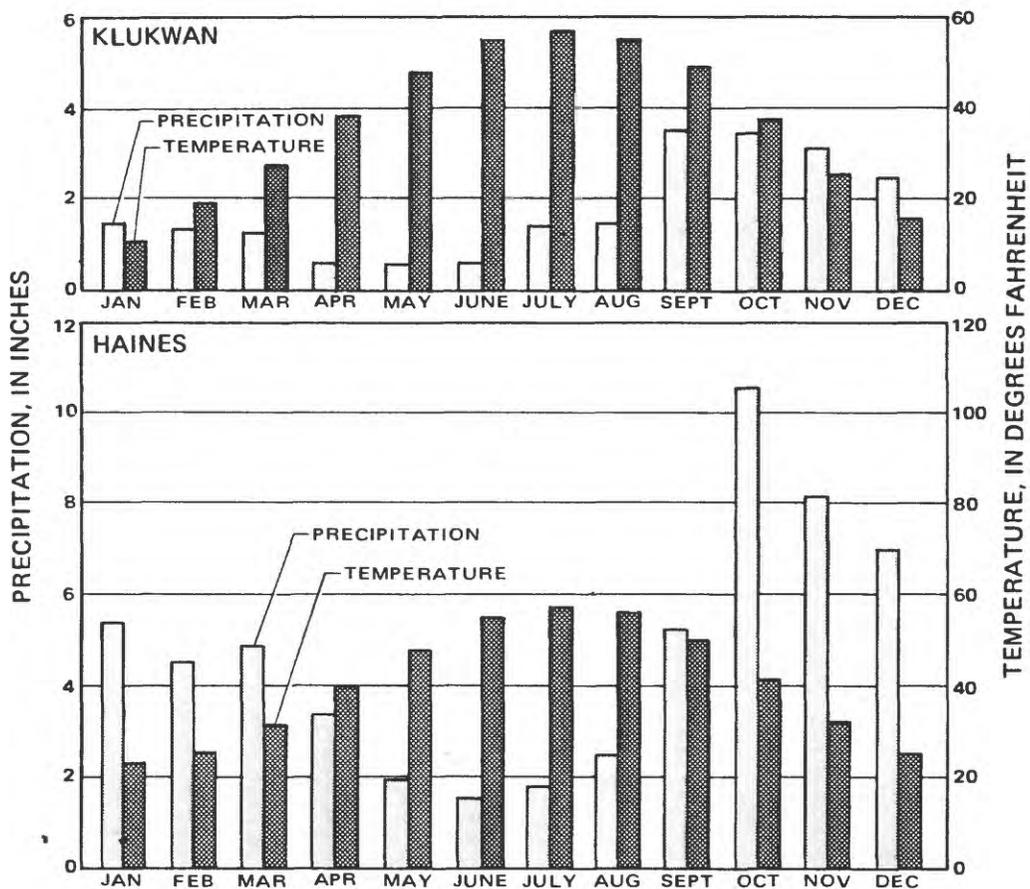
Figure 3. -- Comparison of mean monthly values of precipitation and temperature
for Haines and Klukwan,1927-1943 (from Johnson and Twenhofel, 1953).

been mapped by MacKevett and others (1974). East of the fault and Chilkat River,
structural trends are predominantly northwest, as in much of southeast Alaska; west
of the fault and river the structural trends are complex and include west-trending
faults and lineaments.

The rocks east of the Chilkat River consist of intrusives and metavolcanics
that range in age from Cretaceous to early Tertiary, from about 100 to 50 million
years old (figs. 4 and 5). West of the river, the basin is underlain by
lithologically diverse, metamorphosed Paleozoic, Cretaceous, and Tertiary rocks,
from 500 to 50 million years old.

GEOMORPHIC AND GLACIAL HISTORY

The geologic history of the Chilkat River basin includes periods of mountain
building which began as late as Cenozoic time (60 million years ago) and presently
continues (Ovenshine and Brew, 1972). This movement produced the rugged, highly
dissected mountains characteristic of the area. The principal land-shaping process
in recent (Quaternary) geologic time has been glaciation, which is still dominant
in the upper parts of the basin. Most types of glacial features can be found in
the Chilkat River basin, including ground moraine which covers much of the bedrock
at lower altitudes, especially in the area of the Tsirku River alluvial fan.

5

135° 55'

59° 25'

TK

Q

Wells

KLUKWAN
ALLUVIAL
FAN

TKPz

25

30

Q

29

BM
226

Q

APPROXIMATE PIPELINE LOCATION

TK

54+0

59° 25'

KLEHINI   RIVER

Glass R.

CHILKAT

Q

36

31

Q

KLUKWAN

34

35

R 55 E
R 56 E

Q

T 28 S
T 29 S

TKPz

3

2

Q

TSIRKU

1

6

CHILKAT

RIVER

Fault
Fault

TKPz

Q

ALLUVIAL

Q

FAULT

59° 22' 30"

TKPz

Q

10

Q

RIVER

11

12

FAN

7

8

Q

TSIRKU

TKPz

Fault

TKPz

Fault

Fault

Q

Q

15

Chilkat Lake

13

18

17
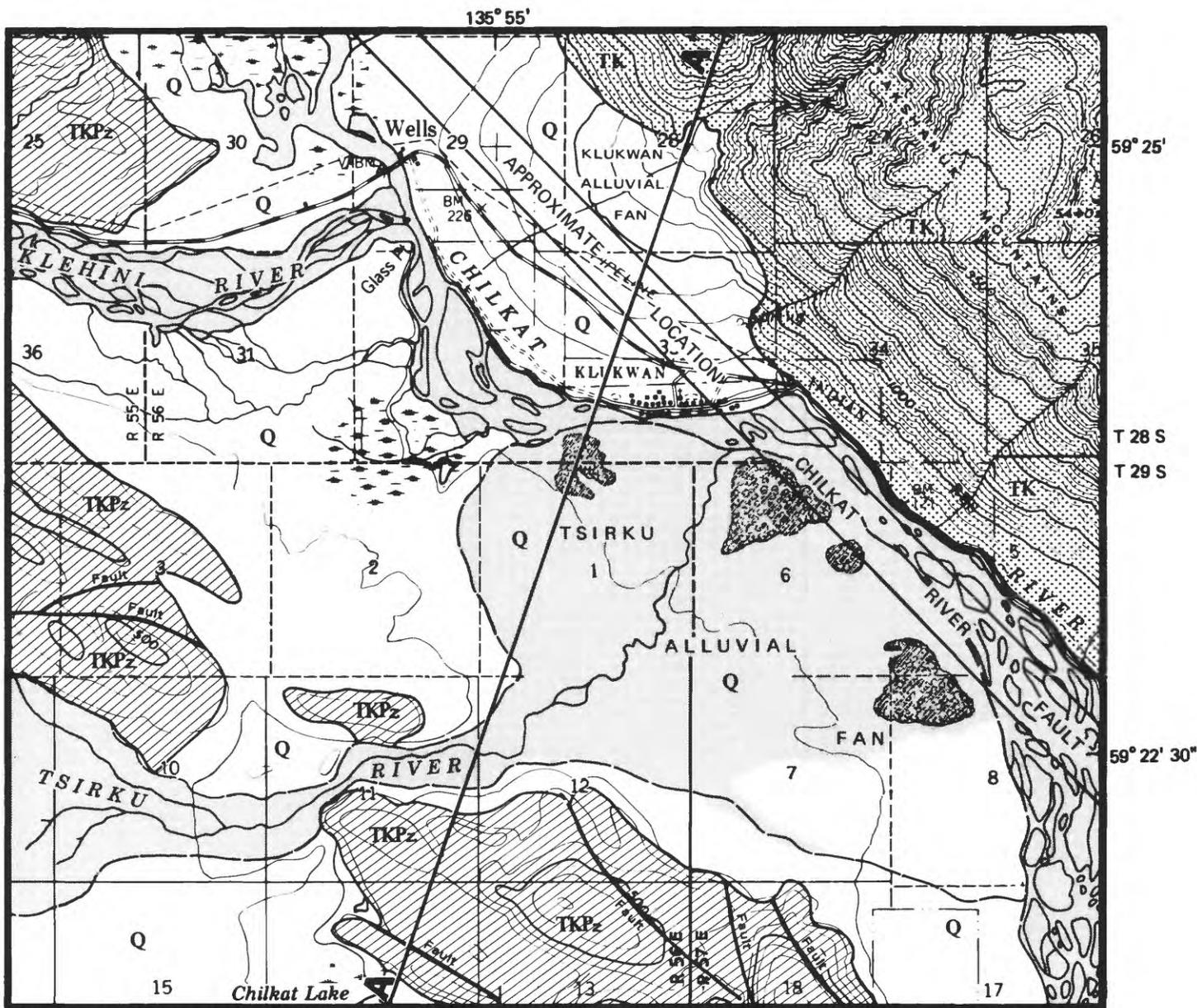
Base from U.S. Geological Survey, 1:63,360, Skagway B-3, B-4, 1954

Geology from MacKevett and others, 1974

0   ½   1   2 MILES

0   .5   1   2   3 KILOMETERS

CONTOUR INTERVAL 100 FEET — DATUM IS SEA LEVEL

EXPLANATION

| Q | TK | TKPz |
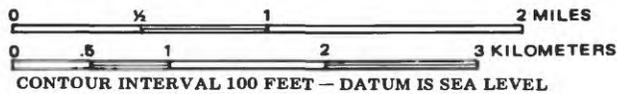
UNDIVIDED SURFICIAL DEPOSITS

Include old and modern alluvium, undifferentiated glacial deposits, and colluvium of Quaternary age. Screened area approximate area flooded during summer high water.

IGNEOUS ROCKS

Intrusive and metamorphosed volcanic rocks including metabasalts, gabbro and diorite, and mafic and felsic dikes of Tertiary and Cretaceous age.

INTRUSIVE AND METAMORPHOSED SEDIMENTARY ROCKS

Lithologically diverse metamorphosed sedimentary rocks including marbles, schist, slate, gneiss, and various diorites of Tertiary, Cretaceous, and Paleozoic age.

A   A'   Line of cross section (see figure 5)

Fault

Figure 4. -- Surficial geology of the Tsirku alluvial fan area near Klukwan.
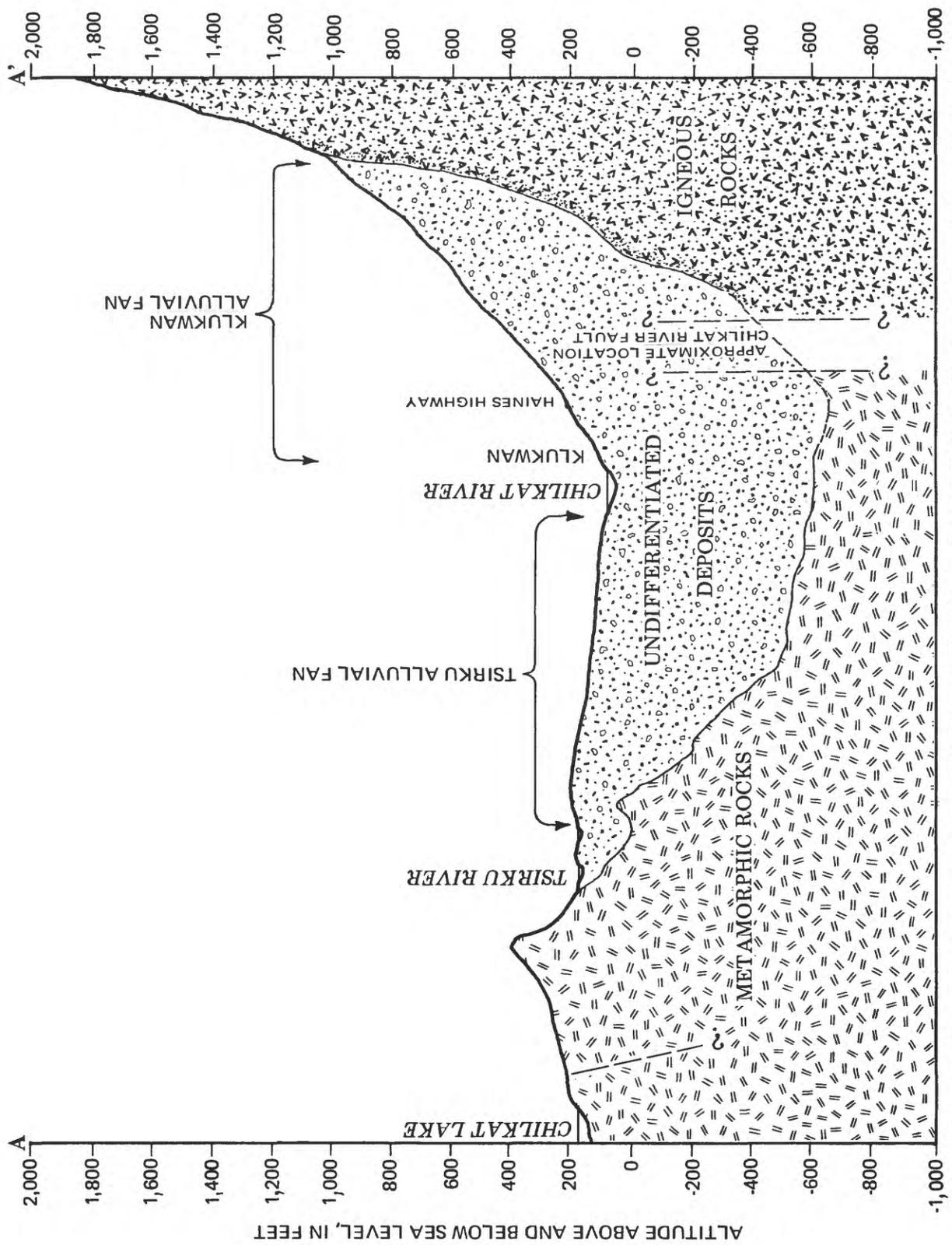
Figure 5. -- Schematic geologic section of Tsirku alluvial fan area near Klukwan (line of section A-A' on figure 4).

ALTITUDE ABOVE AND BELOW SEA LEVEL, IN FEET

7

The complex glacial history includes multiple, basin-wide glaciations and local fluctuations of individual glaciers. The last advance of ice into the lower altitudes of the valleys (at least as far downvalley as the Tsirku alluvial fan) may have been as recent as about 1,700 years or as early as about 11,000 years before present (McKenzie and Goldthwait, 1971). Multiple Wisconsin glacial fluctuations in the study area have not been defined, but the fluctuations probably paralleled those in Adams Inlet of Glacier Bay National Monument (McKenzie and Goldthwait, 1971).

Topographic maps compiled from aerial photographs taken in 1962 show about 25 percent of the Chilkat River basin covered by glaciers. Ice cover within the major subbasins ranges from 5 to 37 percent (table 1). More recent observations and aerial photographs indicate the glaciers have been retreating during the past 30 years (L. R. Mayo, U.S. Geological Survey, oral commun., 1982), so that present-day ice cover in the basin is probably less than that shown on the maps.

Table 1.—Percentage ice cover in the major subbasins within the Chilkat River basin

Subbasin	Ice cover (percent)
Chilkat Lake	5
Kelsall River	5
Klehini River	22
Tahini River	10
Takhin River	37
Tsirku River	35

SURFACE WATER

Chilkat Lake

There are many glacial lakes in the Chilkat River basin, but only three—Duff, Kelsall, and Chilkat—have areas equal to or greater than 0.5 mi^2. Chilkat Lake, the only one of these three that lies within Alaska, occupies a glacially scoured, fault valley about 3 mi southwest of Klukwan (fig. 2). The lake was formed by blockage at its northwest end either as the glacier that occupied the valley retreated toward the northwest, or as outwash debris from the glacier accumulated to its present altitude of about 200 ft. A former outlet at an altitude of 300 to 400 ft (sec. 17 and 19, T. 29 S., R. 57 E.; fig. 6) suggests that the present outlet was once dammed by a glacier. The older outlet has since been abandoned for the present, lower one located between the lake and the Tsirku River (fig. 6). The lake is now about 6 mi long, 1.5 mi at the widest spot, and has an area of about 4 mi^2. The greatest measured depth was more than 200 ft.

Inflow to Chilkat Lake is derived from perennial and intermittent streams that drain an area of 43 mi^2, about 5 percent of which is ice covered. Some ground

8

135°56'55"
59°22'55"

TSIRKU RIVER
TSIRKU
ALLUVIAL

PRESENT LAKE OUTLET

FAN

CHILKAT RIVER

17

50

100

150

19

25

50

PREVIOUS LAKE OUTLET

150

200

175

CHILKAT LAKE

31

36

T 29 S
T 30 S

1

R 56 E
R 57 E

6

30

59°19'24"
135°56'50"

0   1   2 MILES

0   1   2   3 KILOMETERS

DEPTH CONTOUR INTERVALS 25, 30, AND 50 FEET
WATER-SURFACE ALTITUDE 175 FEET

EXPLANATION

▽ Sampling site   Island
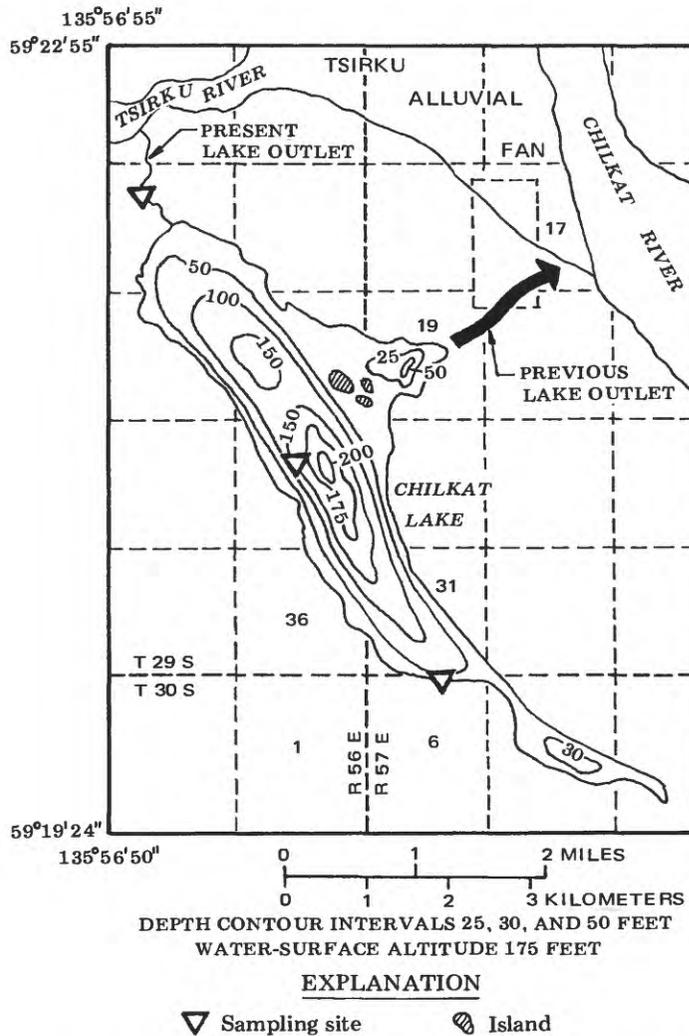
Figure 6. -- Bathymetric map and water-quality sampling
sites at Chilkat Lake near Klukwan.

water flows to the lake from the highly fractured bedrock and numerous faults in
the area. No direct measurements of such inflow have been made. Outflow is pri-
marily via a stream to the Tsirku River. Discharge at the lake outlet, measured at
both high- and low-flow conditions, was 304 ft^3/s on August 18, 1981 and 27 ft^3/s
on April 6, 1982.

Vertical profiles of temperature, specific conductance, pH, and dissolved-
oxygen concentration were measured at a site (fig. 6) on Chilkat Lake on
August 18, 1981 and March 15, 1983 (fig. 7). Two samples were collected on each
date, one at midepilimnion (20 to 25 ft) and one at mid-hypolimnion (100 to 125
ft). Samples were analyzed for major inorganic constituents, nutrients, selected
trace metals, and total organic carbon (table 2).

The calcium bicarbonate water of Chilkat Lake differs only slightly in
chemical makeup between the epilimnion and hypolimnion (fig. 8). The waters of
the lake and of a major stream entering the southern end of the lake are chemically
similar (table 2). The higher concentration of dissolved solids at the outlet of
the lake on April 6, 1982 (fig. 8) probably reflects the increase in relative

9
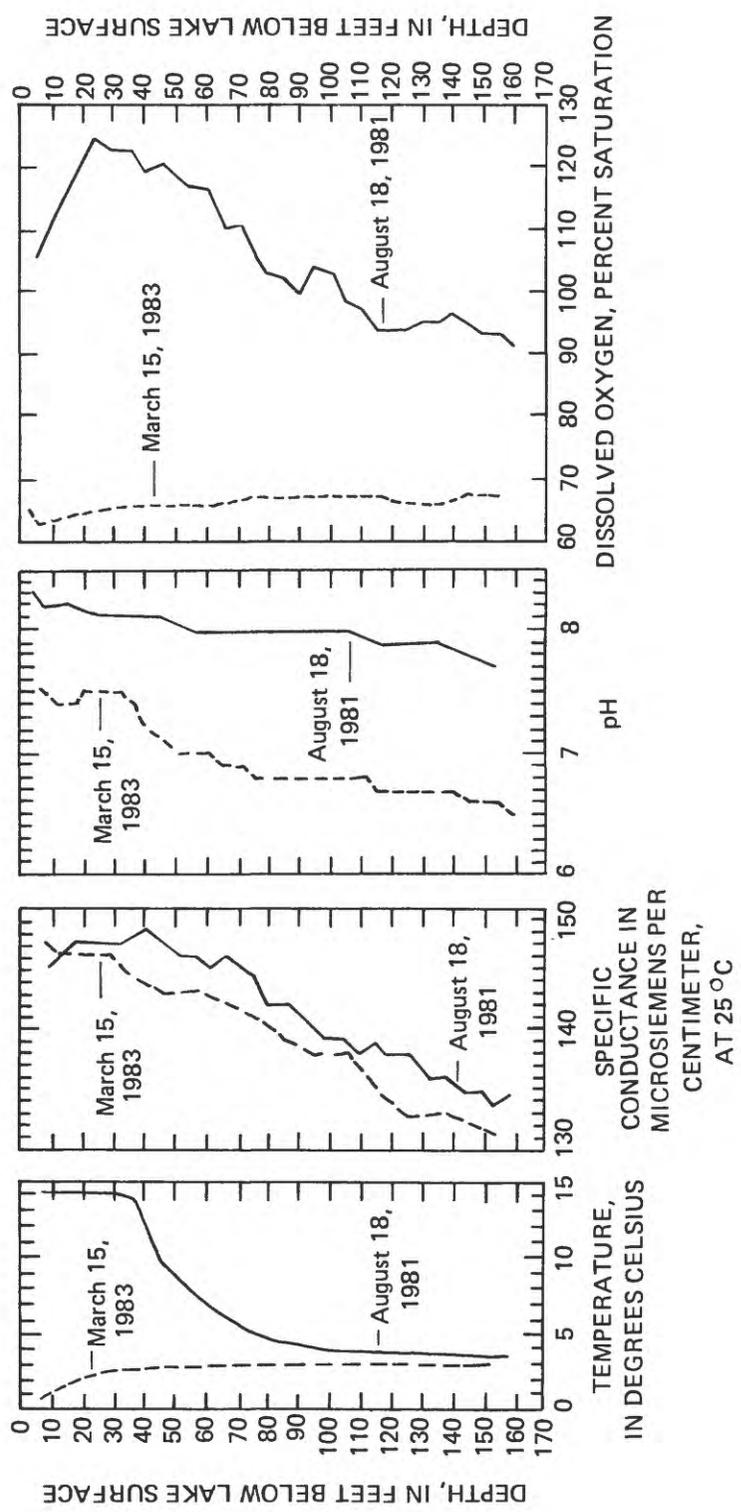
Figure 7.--Temperature, specific conductance, pH, and dissolved-oxygen profiles of Chilkat Lake.

Table 2.--Surface-water quality data for selected sites in the Chilkat River basin, 1981-83

[ft, foot; ft³/s, cubic foot per second; μS/cm at 25° C, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; NTU, nephelometric turbidity unit; --,no data]

| Parameters and constituents	C-1 Chilkat River near Klukwan 8-15-81	C-1 4-6-82	C-2 Klehini River near Klukwan 8-16-81	C-2 4-7-82	C-3 Tsirku River above fan 8-19-81	C-3 4-6-82	C-4 Takhin River at mouth 8-22-81	C-5 Chilkat Lake tributary 8-18-81	L-1 Chilkat Lake SW of islands near Klukwan 8-18-81	L-1 8-18-81	L-1 3-15-83	L-1 3-15-83
Parameter												
Depth, sample (ft)	--	--	--	--	--	--	--	--	20	100	125	25
Discharge (ft³/s)	7,100	300	3,510	190	5,390	140	730	--	--	--	--	--
Specific conductance (μS/cm at 25°C)	47	--	151	--	169	140	88	160	147	139	143	145
Temperature (°C)	7.0	--	8.0	5.5	6.0	6.0	4.0	6.5	14.0	4.0	3.0	2.3
pH	6.8	5.7	7.7	--	7.6	7.5	7.7	7.3	7.5	6.8	7.9	8.1
Turbidity (NTU)	42	2.0	160	.90	430	1.2	130	.90	.90	.70	.40	.70
Constituent concentration, in milligrams per liter												
Suspended sediment	361	16	716	1.0	1,530	1.0	--	--	--	--	--	--
Dissolved oxygen	12.4	--	12.0	--	10.8	12.6	12.4	12.3	12.4	13.4	8.9	9.0
Hardness	16	109	76	131	77	127	53	74	73	75	75	82
Calcium, dissolved	5	33	25	39	26	41	19	27	26	27	27	29
Magnesium, dissolved	.8	6.4	3.2	8.2	3.0	6.0	1.4	1.7	1.9	1.9	1.9	2.3
Sodium, dissolved	.6	8.3	.9	2.5	.9	1.6	.6	1.3	1.3	1.7	1.9	1.9
Potassium, dissolved	1.0	2.6	1.6	2.1	1.2	1.7	1.2	1.3	1.1	1.1	1.0	1.0
Alkalinity	16.0	95	48	93	59	86	47	35	57	55	59	47
Sulfate, dissolved	5.0	26	23	41	25	42	<5.0	34	17	16	18	19
Chloride, dissolved	1.2	8.3	1.2	.6	.4	1.2	2.6	.5	3.2	1.8	4.1	18
Fluoride, dissolved	.0	.1	.0	<.1	.0	<.1	.0	.0	.0	.0	<.1	<.1
Nitrogen, ammonia	.14	.18	.09	.06	.1	.08	.09	--	.110	.080	--	--
Nitrogen, nitrite + nitrate	.19	.23	.05	.22	.08	.24	.09	--	--	--	--	--
Nitrogen, ammonia plus organic	.82	.56	<.20	.10	<.20	.30	.41	--	--	--	--	--
Phosphorus, dissolved	.03	.010	.020	.010	.020	.010	.030	.020	--	--	.010	.010
Carbon, organic dissolved	4.0	1.2	.7	1.0	2.1	1.4	.8	1.3	--	--	--	1.8
Carbon, organic suspended	2.1	.1	1.1	.1	>4.0	<.1	2.5	.4	--	--	--	1.9
Total recoverable constituent concentration, in micrograms per liter												
Arsenic	0.0	1	2	<1	3	1	4	0	0	0	<1	<1
Barium	100.0	<100	200	100	400	100	200	0	0	0	100	100
Copper	50.0	4	60	3	60	3	17	5	4	4	4	2
Iron	4,900	1,600	20,000	170	53,000	120	12,000	320	70	60	90	70
Lead	48	<1	68	2	29	2	8	6	21	9	9	2
Manganese	100.0	150	420	20	1,000	20	240	10	10	10	<10	<10
Mercury	.3	.1	1.0	<.1	1.3	<.1	.4	.1	.1	.3	.2	.1
Selenium	.0	<.1	<1	1	2	1	0	1	0	0	1	1
Silver	.0	<.1	<1	<1	0	1	0	0	<1	<1	<1	<1
Zinc	60	10	10	10	180	10	40	20	10	10	10	20

Table 2.--Surface-water quality data for selected sites in the Chilkat River basin, 1981-83--Continued

| Parameters and constituents	C-6 Chilkat Lake outlet near Klukwan 8-18-81	C-7 Chilkat River below Klukwan 2-10-83	C-8 Unnamed Creek on Klukwan Fan 8-23-81	C-8 Unnamed Creek on Klukwan Fan 5-26-82	C-9 Glacier Creek 8-25-81	C-10 Little Boulder Creek 4-9-82	C-11 Klehini River above Canadian Border 8-21-81
Parameter							
Depth, sample (ft)	--	--	--	--	--	--	--
Discharge (ft³/s)	300	--	7.2	--	--	21	--
Specific conductance (µS/cm at 25°C)	--	278	322	330	144	120	59
Temperature (°C)	--	.4	6.5	6.0	4.5	3.0	5.5
pH	--	8.0	7.1	7.5	7.5	8.3	7.7
Turbidity (NTU)	2.0	1.5	6.8	--	25	.20	200
Constituent concentration, in milligrams per liter							
Suspended sediment	--	--	--	11.5	--	--	--
Dissolved oxygen	--	10.5	12.0	--	12.9	--	12.4
Hardness	73	127	144	--	72	133	44
Calcium, dissolved	26.	40	52	--	26	42	16
Magnesium, dissolved	1.9	6.6	3.5	--	1.8	6.8	1.1
Sodium, dissolved	1.3	7.3	1.7	--	.6	1.9	.9
Potassium, dissolved	1.0	5.6	.8	--	1.6	2.8	.7
Alkalinity	50	104	35	--	45	99	38
Sulfate, dissolved	17	34	100	--	29	39	<5.0
Chloride, dissolved	1.0	5.5	2.7	--	.2	.8	<.1
Fluoride, dissolved	.0	<.1	.0	--	0	<.1	.1
Nitrogen, ammonia	--	--	.09	--	.07	.08	.13
Nitrogen, nitrite + nitrate	--	--	1.0	--	.07	.51	1.7
Nitrogen, ammonia plus organic	--	--	.36	--	.45	.65	.69
Phosphorus, dissolved	--	.020	.020	--	<.010	.050	.020
Carbon, organic dissolved	--	1.9	.5	--	.7	.5	1.5
Carbon, organic suspended	--	.1	.7	--	.7	.1	3.6
Total recoverable constituent concentration, in micrograms per liter							
Arsenic	1	1	2	--	0	<1	3
Barium	0	<100	0	--	100	<100	0
Copper	7	2	23	--	14	2	54
Iron	250	230	2,900	--	6,200	20	32,000
Lead	920	4	15	--	6	<1	11
Manganese	10	80	50	--	130	<10	730
Mercury	.1	.6	.1	--	.5	<.1	.7
Selenium	0	1	1	--	1	1	0
Silver	0	<1	.0	--	1	<1	0
Zinc	10	10	20	--	40	10	120

EXPLANATION
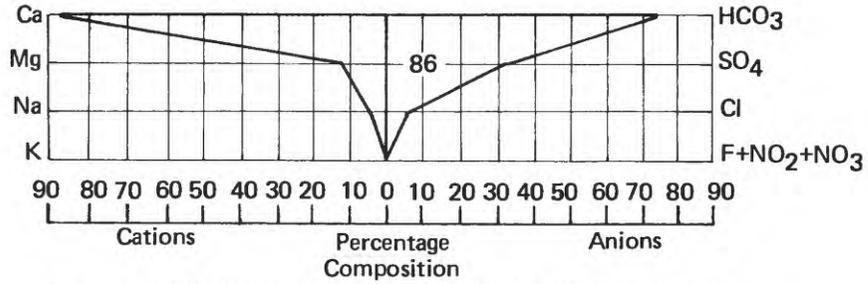
Number inside diagram represents dissolved solids concentration
in milligrams per liter
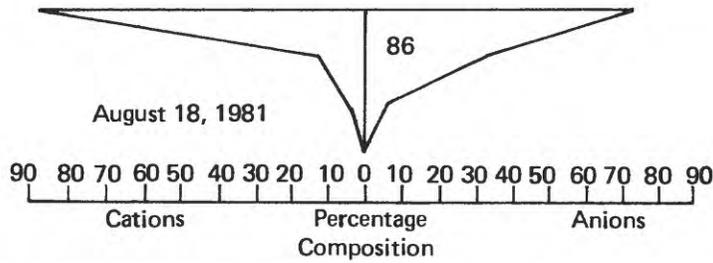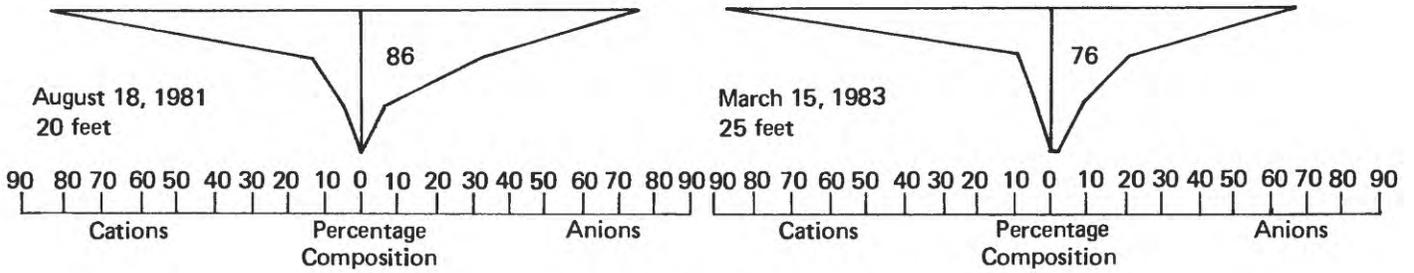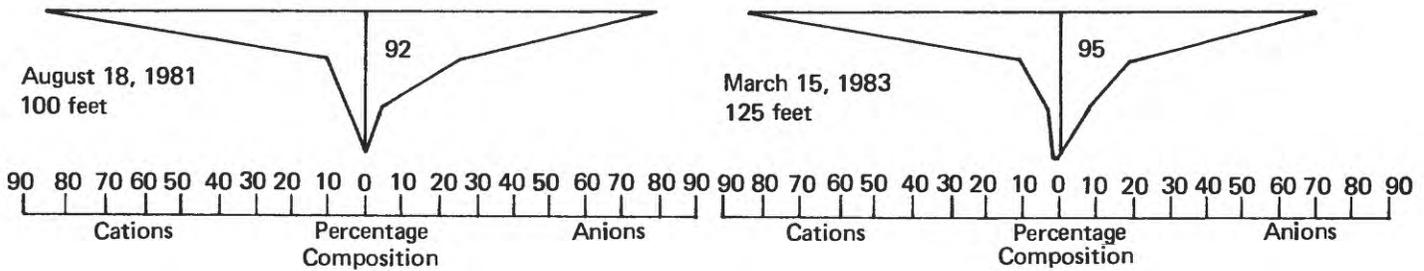
Figure 8.--Percentage composition of major cations and anions, and dissolved-solids concentration
for Chilkat Lake and its outlet stream.

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amounts of ground-water discharge to that area during the winter low-flow period (see section "Tsirku Fan Flow System"). The depth profiles indicate that on August 18, 1981, the lake was thermally stratified at about 35 ft below the water surface. Because of the similarity of the epilimnion and hypolimnion water quality and thermal stratification, it appears that the lake experienced at least one complete mixing cycle that year. Such mixing probably occurs yearly.

Flooding of Tsirku River into Chilkat Lake has occurred several times in recent years. During periods of high flow, a branch of the Tsirku River may overtop its bank, flow through the flat tree- and marsh-covered area at the northwest end of the lake and discharge into the lake. This phenomenon, which occurred in 1981, has been aided recently by an abandoned airplane runway that channels water from Tsirku River toward Chilkat Lake. The flood waters carry high concentrations of suspended sediment, mostly silt and clay, that could affect salmon spawning areas in the lake. Fisheries biologists generally agree that excessive amounts of fine sediments in spawning gravels increase salmonid embryo and larval mortality (Shirazi and Seim, 1981).

Streamflow

Streamflow in the Chilkat River basin originates as runoff from precipitation (rain or melting snow and ice) and as ground water discharged to the streams from springs and seeps along or in riverbeds. Runoff from melting glacier snow and ice augments streamflow during summer months. The volume of runoff in any given area is a function of precipitation, amount of snow and ice melt, size and surficial geology of the drainage area and the amount of evaporation and plant transpiration (evapotranspiration). Because of the relatively high humidity and cloudiness in much of the Chilkat River basin throughout the summer, evaporation is probably less significant than the other determinants of runoff. Ground-water discharge from seeps and springs contributes a large part of the flow of many streams during winter low-flow periods.

Streamflow measurements were made in periods of high and low flow at selected sites on the Chilkat River and on most of its major tributaries, including the Takhin, Klehini, and Tsirku Rivers, and the outlet of Chilkat Lake (fig. 9 and table 3). Miscellaneous measurements were made on several smaller streams within the Chilkat River basin.

A continuous-recording gaging station was established on the Klehini River in October 1981. The discharge pattern of the Klehini River is typical of that for glacier-fed streams in this region of southeast Alaska (fig. 10). Sustained high flows occur during periods of greatest glacier melt, normally June, July, and August. The highest flows during early fall are usually caused by rainfall. Lowest flows usually occur from midwinter to midspring, when ground-water discharge sustains flow in the Klehini and other rivers.

On the basis of streamflow measurements, discharge of the Tsirku River correlates closely with that of the Klehini River (fig. 11), because their basins have similar physiographic and hydrologic characteristics. Owing to the similarities of the basins, monthly and annual mean flow of the Tsirku River can be estimated from the continuous record on the Klehini River using techniques

Figure 9. -- Continuous-record gaging station and miscellaneous measurement sites in the Chilkat River basin.

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Table 3.--Drainage area, period of record, and maximum and minimum discharge for selected streams measured in the Chilkat River basin

[mi², square mile; ft³/s, cubic foot per second]

Map No. (fig. 9)	Station No.	Stream	Drainage area (mi²)	Period of record	Discharge (ft³/s) Maximum	Minimum
C-1	15056500	Chilkat River near Klukwan.	760	[1]1959-1961 1981-1982	[3]20,400 [3]7,100	80 300
C-2	15056560	Klehini River near Klukwan.	245	[2]1981 [1]1982-1983	9,000	116
C-3	15056580	Tsirku River near Klukwan.	230	[2]1981-1983	5,390	142
C-4	591630135410200	Takhin River at mouth.	100	[2]1981-1982	722	--
C-8	592436135545000	Unnamed creek south of Wells near Klukwan.	[4]2	[2]1981-1982	4	0
C-10	592546136074700	Little Boulder Creek.	25	[2]1981-1982	92	21

[1] Continuous streamflow record.
[2] Miscellaneous measurements only.
[3] Mean flow for periods of record is 3,261 ft³/s.
[4] Approximate.
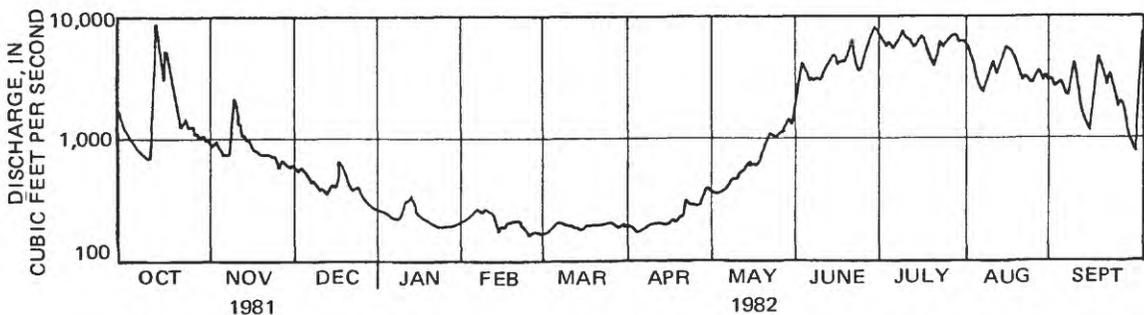
Figure 10.--Hydrograph for Klehini River (15056560), October 1981 to September 1982.
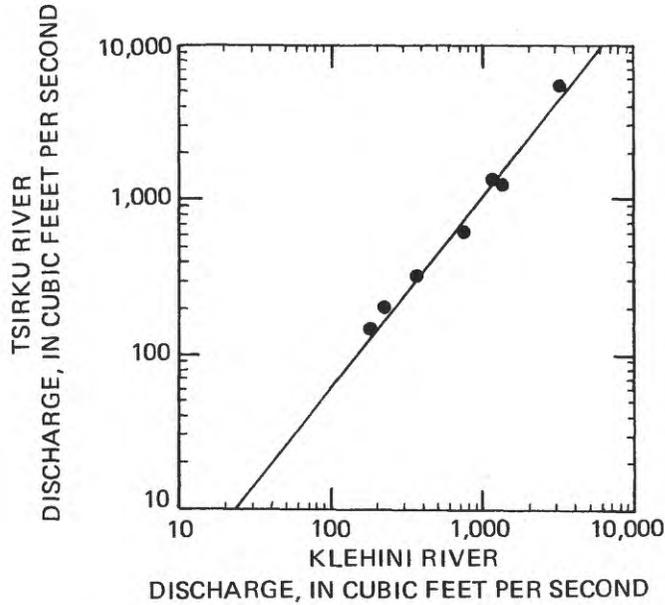
Figure 11.--Discharge relation between Klehini
and Tsirku Rivers.

described by Riggs (1969). The Tsirku River also exhibits the same seasonal streamflow fluctuations as the Klehini River (table 4).

A seepage run, a series of stream discharge measurements along a stream reach, was made in the Tsirku alluvial fan area on April 6, 1982, during an early spring low-flow period (fig. 12). Comparison of discharge measurements indicates that, of a total flow of 142 ft³/s at the head of the fan, 74 ft³/s, or 52 percent of that flow, was from the Little Salmon River and 68 ft³/s, or 48 percent, was from Clear Creek. About half the flow of Clear Creek at its mouth was derived from Chilkat Lake.

Table 4.- Monthly mean flow for Klehini and Tsirku Rivers, 1982 water year
(Oct. 1, 1981 - Sept. 30, 1982)

| Stream | Monthly mean flow, in cubic feet per second | | | | | | | | | | | | Annual mean |
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
Klehini River	2,012	905	446	244	217	199	238	789	4,266	5,424	3,293	2,329	1,706
Tsirku River	2,500	900	345	185	155	143	177	780	6,200	8,600	4,600	2,950	2,000

17
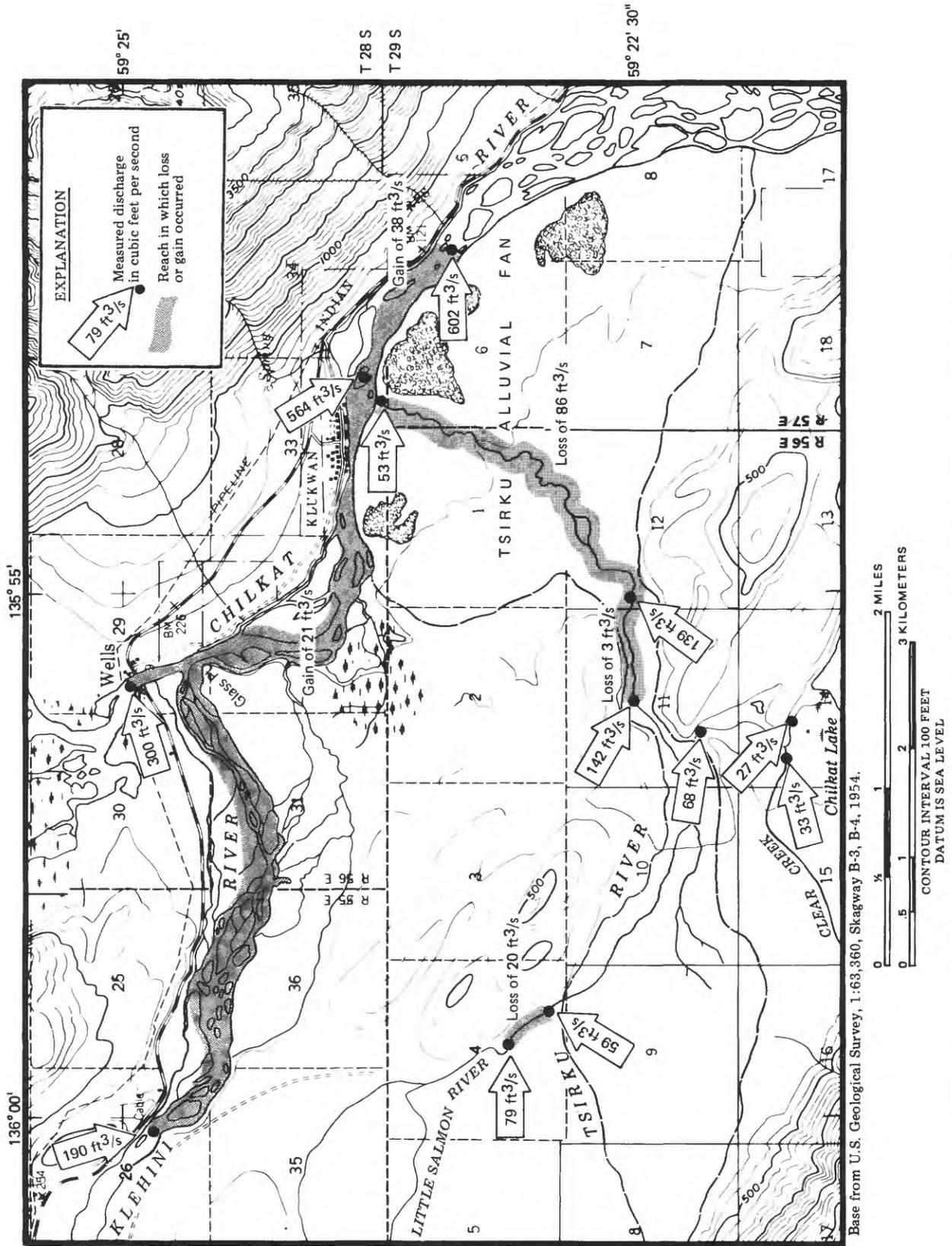
Figure 12. -- Losses and gains in streamflow in the Tsirku River alluvial fan area, April 6, 1982.

Base from U.S. Geological Survey, 1:63,360, Skagway B-3, B-4, 1954.

CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

79 ft3/s — Measured discharge in cubic feet per second

Reach in which loss or gain occurred

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Chemical Quality

Throughout the basin, surface water is generally a calcium bicarbonate type (fig. 13 and table 2), except in an unnamed stream (site C-8) on the Klukwan alluvial fan east of the community of Klukwan. This stream had a greater concentration of dissolved sulfate and a greater specific conductance than other sites sampled. Iron concentration may be very high (up to 53,000 μg/L in the Tsirku River on August 19, 1981), especially during summer high-flow periods on all streams sampled within the basin (table 2). Anomalously high concentrations of barium in the Klehini, Tsirku, and Takhin Rivers and Glacier Creek, probably reflect the presence of barite deposits in these basins (MacKevett and others, 1974). Water temperatures in glacial streams ranged from near freezing in winter to 6 °C during the summer months. Small nonglacial streams can be expected to be somewhat warmer than glacier-fed streams in summer months.

Suspended Sediment

Suspended-sediment samples were collected during high- and low-flow periods in August 1981 and April 1982, respectively, on the Chilkat River, the Tsirku River above Tsirku alluvial fan, and the Klehini River. Although there are not enough data to compute statistically valid sediment concentrations on a monthly or yearly basis, some general conclusions can be drawn from the information available.

At low-flow conditions, all three rivers carried relatively low concentrations of suspended sediment (1-16 mg/L or 0.38-13 ton/d) in comparison to the concentration at higher flow periods (361-1,530 mg/L or 6,360-22,300 ton/d) (table 2). During the low-flow sampling, the Chilkat River carried almost 20 times more suspended sediment than the Tsirku or Klehini Rivers (fig. 14). This is most likely a function of stream gradients and available material, which consists mostly of fine-grained sediment in the Chilkat River near Klukwan but coarse material in the Tsirku and Klehini Rivers. At high flow, the suspended-sediment load increases by three to four orders of magnitude in each stream (fig. 14). At high flows, however, the Tsirku River carries a slightly greater sediment load than the Klehini and Chilkat Rivers. This higher sediment load is probably due in part to a greater abundance of glaciers (and their included debris) in the Tsirku basin.

GROUND WATER

Ground water in the Chilkat River basin occurs under unconfined and confined conditions in bedrock and alluvium. Unconfined ground water is usually found in alluvium in valleys, but confined conditions may occur in alluvium overlain by clay and silt at depth or at the base of steep alluvial fans on the sides of mountains, and in fractured bedrock beneath valleys.

Bedrock aquifers in the Chilkat basin transmit water through secondary structures such as fractures and joints. Primary porosity (created during formation of the rocks) is probably negligible. Permeability of the rocks may be greater near faults where rock movement has caused more intensive fracturing. However, no data are available to quantify bedrock permeability.

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Figure 13. -- Surface-water quality sites in Chilkat River basin, percentage of major cations and anions, and total hardness.

20
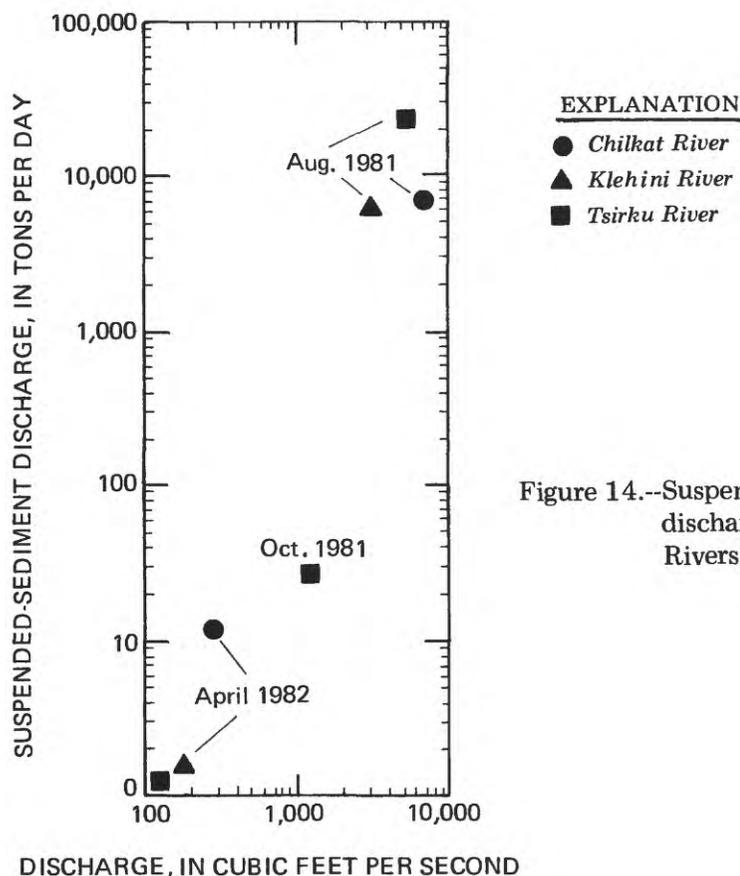
Figure 14.--Suspended-sediment discharge versus stream discharge for Chilkat, Klehini, and Tsirku Rivers at high-and low-flow periods.

Alluvial/colluvial fans along the east side of the Chilkat River valley consist of detritus eroded from the steep flanks of the Takshanuk Mountains. Perennial seeps and springs flowing from these fans into the Chilkat River sustain the flow in small tributary channels that, in many cases, salmon favor for spawning. The Klukwan alluvial fan, a large fan aquifer, supplies water to a spring that is used as a year-round source of water for the village of Klukwan.

Alluvial aquifers that underlie major river valleys are commonly very thick. Data from seismic traverses across the Chilkat River valley near Klukwan indicate that depth to bedrock is greater than 850 ft below land surface (fig. 15). A seismic traverse in the Klehini River valley at mile 27 Haines Highway, indicates depth to bedrock of at least 250 ft. A traverse across the flat outwash plain between the Klehini and Tsirku River valleys in the area of the Little Salmon River indicates a depth to bedrock of at least 200 ft. All seismic data were analyzed by the methods of Scott and others (1972).

Interpretation of seismic traverses in the Little Salmon Creek area indicates that unconsolidated gravels are continuous between the Klehini, Tsirku, and Chilkat valleys near the mouth of the Klehini River. Aquifers in these interconnected gravels are probably hydraulically continuous. The water table in those aquifers
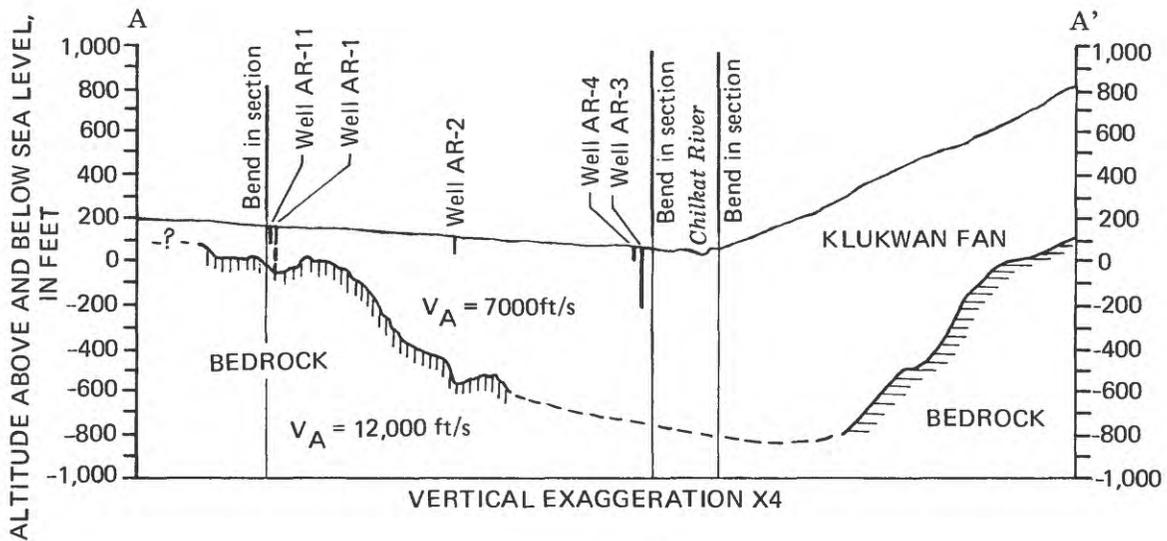
21

Figure 15. -- Cross section across Chilkat Valley and Tsirku alluvial fan showing bedrock depth from seismic refraction and gravimetric data. See figure 17 for location of line A-A'. (Gravimetric data, 1972, from M.M. Holmes, Klukwan Iron Ore Co., written communication.)

has not been mapped in the Klehini Valley nor in much of the Chilkat Valley. However, as in most alluvial-valley aquifers, the water table probably slopes downvalley at approximately the gradient of the valley axis.

Analyses of samples from four of the observation wells indicate that the ground water has a slightly greater dissolved-solids content, but is otherwise chemically similar to the streams. Results of the analyses are on table 5 and shown graphically in figure 16.

TSIRKU RIVER ALLUVIAL FAN

The 5-square-mile Tsirku River alluvial fan is a low-gradient alluvial fan deposited by the Tsirku River as it leaves the confines of its bedrock valley and flows into the Chilkat River valley (fig. 17). The Chilkat River borders the toe
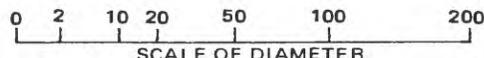
22
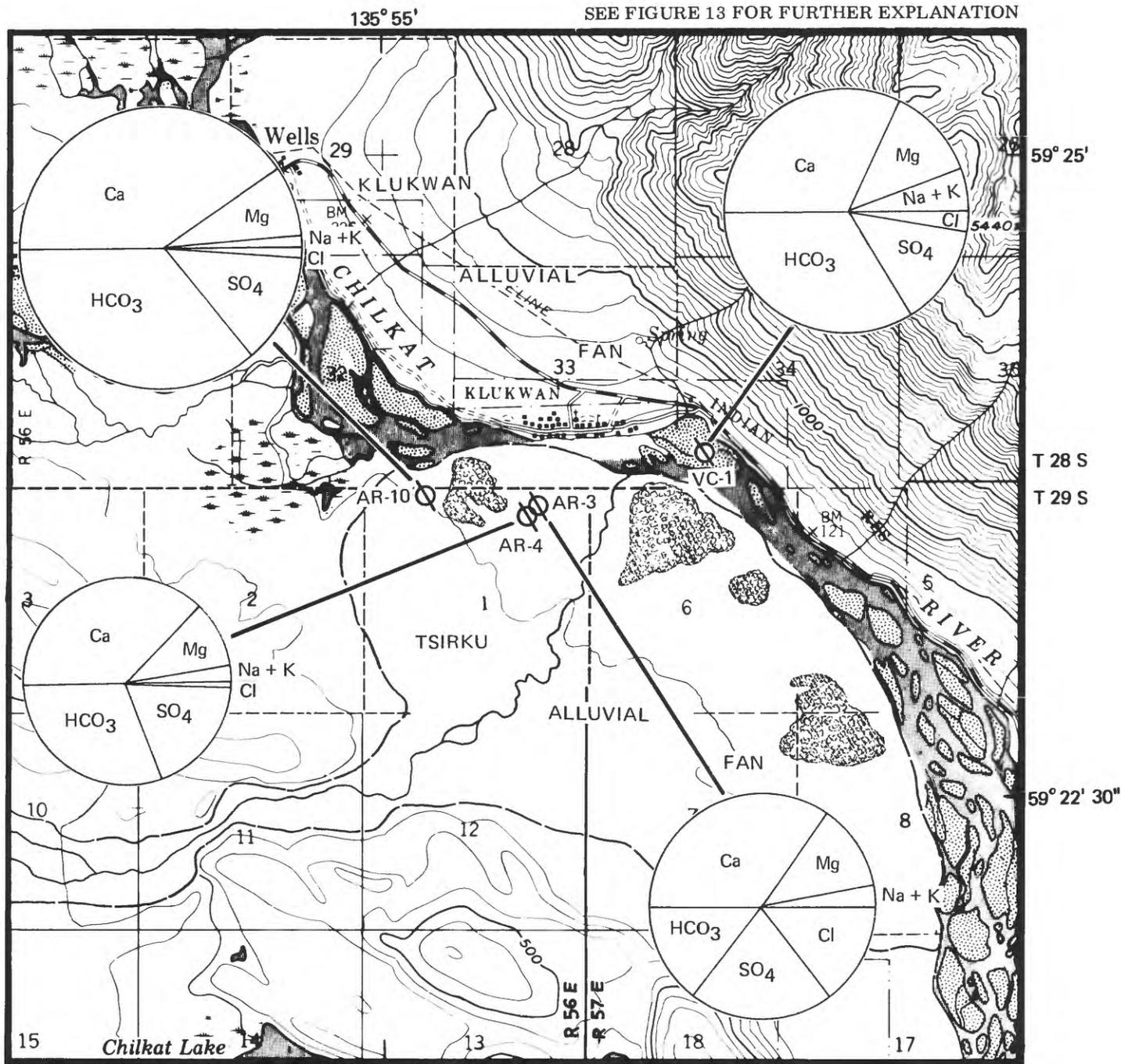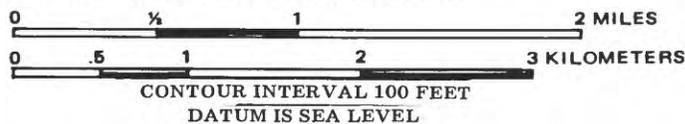
Figure 16. -- Ground-water-quality sites on and near the Tsirku alluvial fan, percentage of major cations and anions, and total hardness.

Table 5.--Ground-water quality data for four observation wells in the Chilkat River basin

[ft, foot; μS/cm at 25° C, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; NTU, nephelometric turbidity unit; --, no data]

| Parameters and constituents	Well No. (fig. 16)- - - Date of sample- - - -	AR-10 3-16-83	AR-3 12-13-82	AR-4 12-13-82	VC-1 2-10-83
		Parameter			
Well depth (ft)- - - - - - - - - - - -		40	260	40	30
Specific conductance (μS/cm at 25° C) - - - - - - - - - - -		360	200	205	250
Temperature (°C) - - - - - - - - - -		6.2	4.5	4.2	4.5
pH - - - - - - - - - - - - - - - - -		7.6	8.2	9.2	8.4
Turbidity (NTU)- - - - - - - - - - -		--	24	32	1.6
		Constituent concentration, in milligrams per liter			
Dissolved oxygen - - - - - - - - - -		--	4.6	4.3	--
Hardness - - - - - - - - - - - - - -		169	88	90	119
Calcium, dissolved - - - - - - - - -		56	26	28	34
Magnesium, dissolved - - - - - - - -		7.0	5.7	4.8	8.2
Sodium, dissolved- - - - - - - - - -		1.5	1.8	1.3	5.8
Potassium, dissolved - - - - - - - -		1.6	1.6	1.5	1.6
Alkalinity - - - - - - - - - - - - -		125	28	59	93
Sulfate, dissolved - - - - - - - - -		46	39	36	36
Chloride, dissolved- - - - - - - - -		.8	20	.8	6.3
Fluoride, dissolved- - - - - - - - -		.1	.1	.1	.1
Nitrogen, $NO_2 + NO_3$ - - - - - - - -		.20	.20	.10	.20
Nitrogen, nitrate- - - - - - - - - -		--	--	.08	--
Nitrogen, nitrite- - - - - - - - - -		<.020	<.020	.020	<.070
Nitrogen, ammonia- - - - - - - - - -		<.060	.130	.060	<.060
Phosphorus, as P - - - - - - - - - -		.020	.030	.050	.030
Phosphorus, as PO_4- - - - - - - - -		.06	.09	.15	.09
Phosphorus, ortho- - - - - - - - - -		.020	<.010	.020	.010
Carbon, organic- - - - - - - - - - -		1.0	2.3	2.6	.7
		Total recoverable constituent concentration, in micrograms per liter			
Arsenic- - - - - - - - - - - - - - -		1	1	1	1
Barium - - - - - - - - - - - - - - -		< 100	< 100	< 100	< 100
Copper - - - - - - - - - - - - - - -		4	9	13	5
Iron - - - - - - - - - - - - - - - -		580	14,000	14,000	300
Lead - - - - - - - - - - - - - - - -		7	52	30	1
Manganese- - - - - - - - - - - - - -		30	530	200	10
Mercury- - - - - - - - - - - - - - -		.1	.4	.3	.7
Selenium - - - - - - - - - - - - - -		2	< 1	< 1	1
Silver - - - - - - - - - - - - - - -		< 1	< 5	< 5	< 1
Zinc - - - - - - - - - - - - - - - -		20	220	70	30
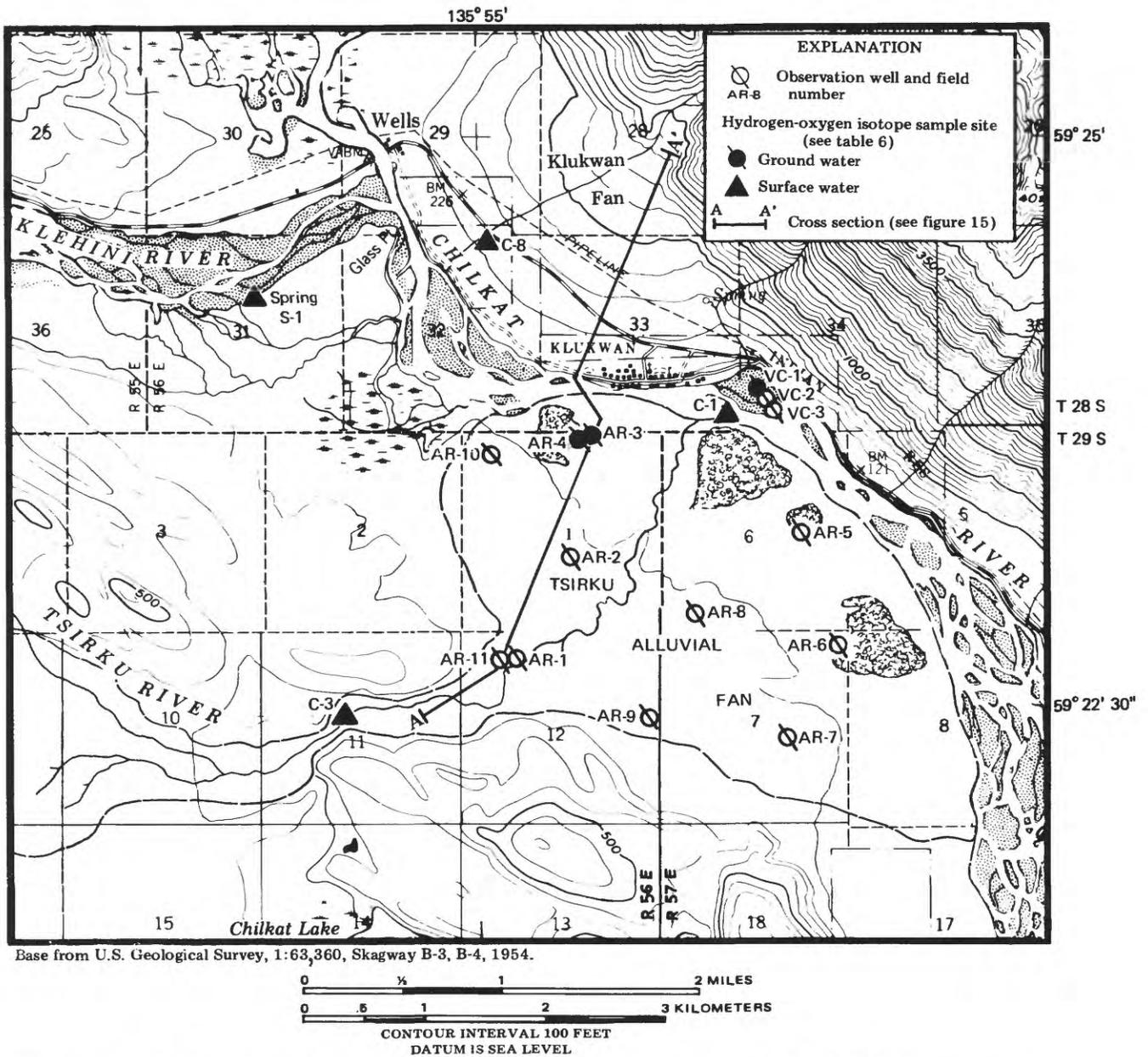
Figure 17. -- Tsirku alluvial fan and vicinity, locations of observation wells (drilled November-January 1982-83), and hydrogen-oxygen isotope sampling sites.

of the fan along the toe's entire 4.9-mile perimeter. During low-flow periods in 1982 and 1983, the main channel on the fan was about 2 mi long. The surface of the fan descends from an altitude of about 160 ft near the head to about 95 ft near the toe. This vertical drop of 65 ft in a distance of about 1.8 mi is equivalent to a gradient of 36 ft/mi, in contrast to a gradient of 48 ft/mi for the Tsirku River directly above the fan.

The fan is composed of material that ranges in size from boulders greater than 1 ft in diameter to silt- and clay-sized particles (fig. 18). Most of the perimeter of the fan is covered by low-lying bushes and grasses growing on inactive channels and on overbank deposits. Stands of cottonwood trees grow along the toe and on the sides of the fan. However, most of the upper and middle parts of the fan are unvegetated or very sparsely vegetated.

Figure 18. -- Tsirku alluvial fan, October 5, 1981. View is northwest toward head of fan (low dark hills in upper part of photograph). Note variance in size of sediment on fan surface. Also note inactive channel in the middle of photograph with finer sediment and typical vegetation growing on fan surface (vegetation is approximately 2.5 feet high).

Glacial History

The Tsirku alluvial fan area presumably underwent multiple glacial episodes as did most of this part of southeast Alaska. The Chilkat River valley and the area of the fan appear to have been ice free earlier than the surrounding areas such as Glacier Bay National Monument (H. J. Kaiser Co., written commun., 1972). During the last major glacial period (about 10,000 years ago), sea level was considerably lower than at present, perhaps by as much as 300 ft.

As glaciers in the Chilkat River valley retreated, large amounts of sediment were deposited as outwash, valley train, and deltaic deposits. An average rate of deposition would have been about 0.1 ft/yr assuming the area became ice free 10,000 years ago and the glacier had scoured to bedrock. This compares with an accretion rate for Klukwan alluvial fan of 0.4 ft/yr calculated from a carbon-14 dated piece of wood (H. J. Kaiser Co., written commun., 1972). The types of sediment filling the valley vary from till (ice-contact materials) to alluvium (outwash materials) to deltaic and marine deposits. The alluvial deposits are better sorted (lesser percentage of silt and clay) than the till.

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The relation of the altitude of the bedrock valley floor in the Tsirku alluvial fan area, at an estimated 850 ft below sea level (fig. 15), to present-day sea level indicates that sea water could have intruded into the valley. Test drilling at the mouth of the Chilkat River, 20 mi downstream, penetrated a marine deposit more than 100 ft thick whose upper surface is 20 ft below present sea level (Alaska Dept. of Highways, 1968). However, no marine deposits were identified in observation well AR-3, which was drilled to a depth of 260 ft below land surface, about 146 ft below present sea level. If the sea once did extend up the Chilkat Valley as far as the Tsirku alluvial fan area, marine deposits may be present at a depth greater than 260 ft.

Fan Sedimentology and Morphology

The composition of sediment and the channel morphology of the Tsirku alluvial fan reflect its depositional history. An alluvial fan is built by both lateral and vertical migration of channels. As sediment is deposited, the channel eventually becomes clogged, resulting in a diversion of water from that channel toward an area that is lower (Fahnestock, 1967). A new channel is then formed, in which the process begins again in the area of the new channel.

The vertical sedimentary structure of the fan is also the result of a repetitive building process. Coarse sediment is selectively deposited by different quantities and velocities of water in the channel. A decrease in velocity results in a decrease in the size of sediment that can be transported until, with a decrease in flow of water, the velocity slows sufficiently so that only silt- and clay-sized material can be transported. Eventually even these fine-grained materials are deposited upon the coarser sediments as flow ceases.

TSIRKU ALLUVIAL FAN AQUIFER

The alluvium of the Tsirku alluvial fan comprises an unconfined aquifer bounded on the northeast and southwest by the bedrock walls of the valley. At the northwest and southeast boundaries the aquifer grades into and is hydraulically continuous with alluvial aquifers of the Klehini and Chilkat Valleys. The base of the aquifer in the eastern part of the Chilkat Valley has not been defined, but is likely to be the contact between alluvial material and low-permeability marine or deltaic deposits at a depth greater than 260 ft below land surface. On the north, the Tsirku alluvial fan sediments interfinger with sediments of the Klukwan alluvial fan (H.J. Kaiser, written commun., 1972). Klukwan alluvial fan sediments are poorly sorted debris-flow deposits of lower permeability than Tsirku alluvial fan sediments.

In the Tsirku alluvial fan aquifer, seasonal fluctuations of the water table are observed in both deep and shallow wells (figs. 19 and 20). In observation well AR-3 (depth, 260 ft), water levels decreased slowly from December 1982 until about mid-April 1983, then rose rapidly at an average of 0.2 ft/d until mid-May 1983. Observation well AR-1 (depth, 220 ft), which is drilled 20 ft into bedrock, shows a similar response, but with a more rapid rise in water level, about 0.6 ft/d from mid-April to mid-May. Shallow wells AR-4 and AR-7 (both 40 ft deep) react similarly. Synchronous fluctuations of water levels in both deep and shallow wells indicate hydraulic continuity between deep and shallow parts of the aquifer.
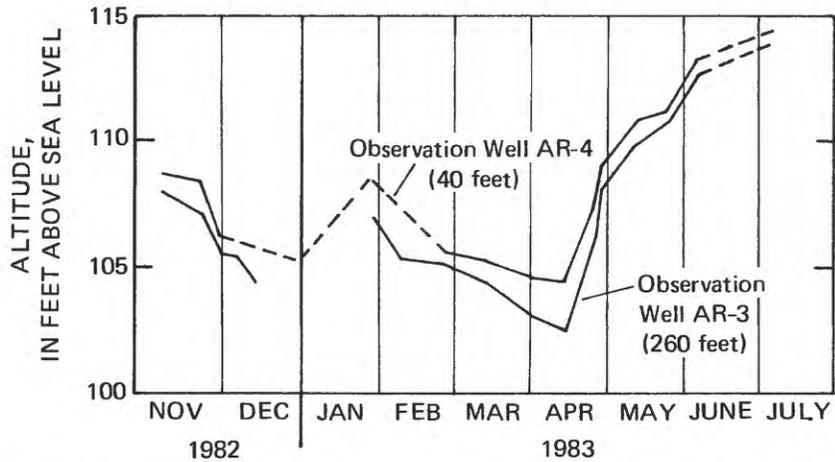
Figure 19. -- Hydrograph of observation wells AR-3 and AR-4 at the toe of the Tsirku alluvial fan showing relation between potentiometric surface in deep and shallow ground-water systems.
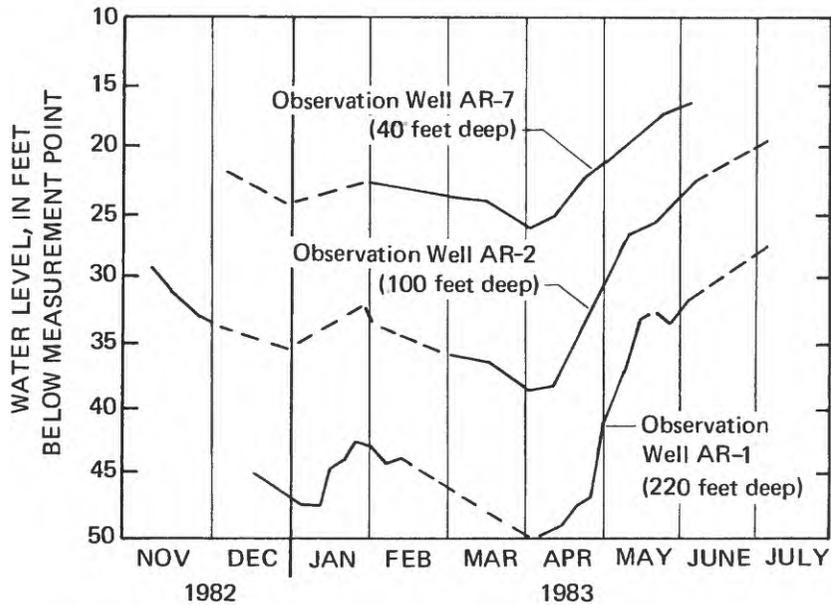
Figure 20. -- Hydrographs of observation wells on the Tsirku alluvial fan.

Flow lines drawn perpendicular to potentiometric-surface contours (fig. 21a and b) indicate that as shallow ground water moves through the head of the fan it spreads out in a deltaic pattern. After the water has moved about one-third of the distance from head to toe of the fan, its direction becomes skewed downvalley. This downvalley trend is most pronounced in late winter (March) data, when the potentiometric surface is lowest.
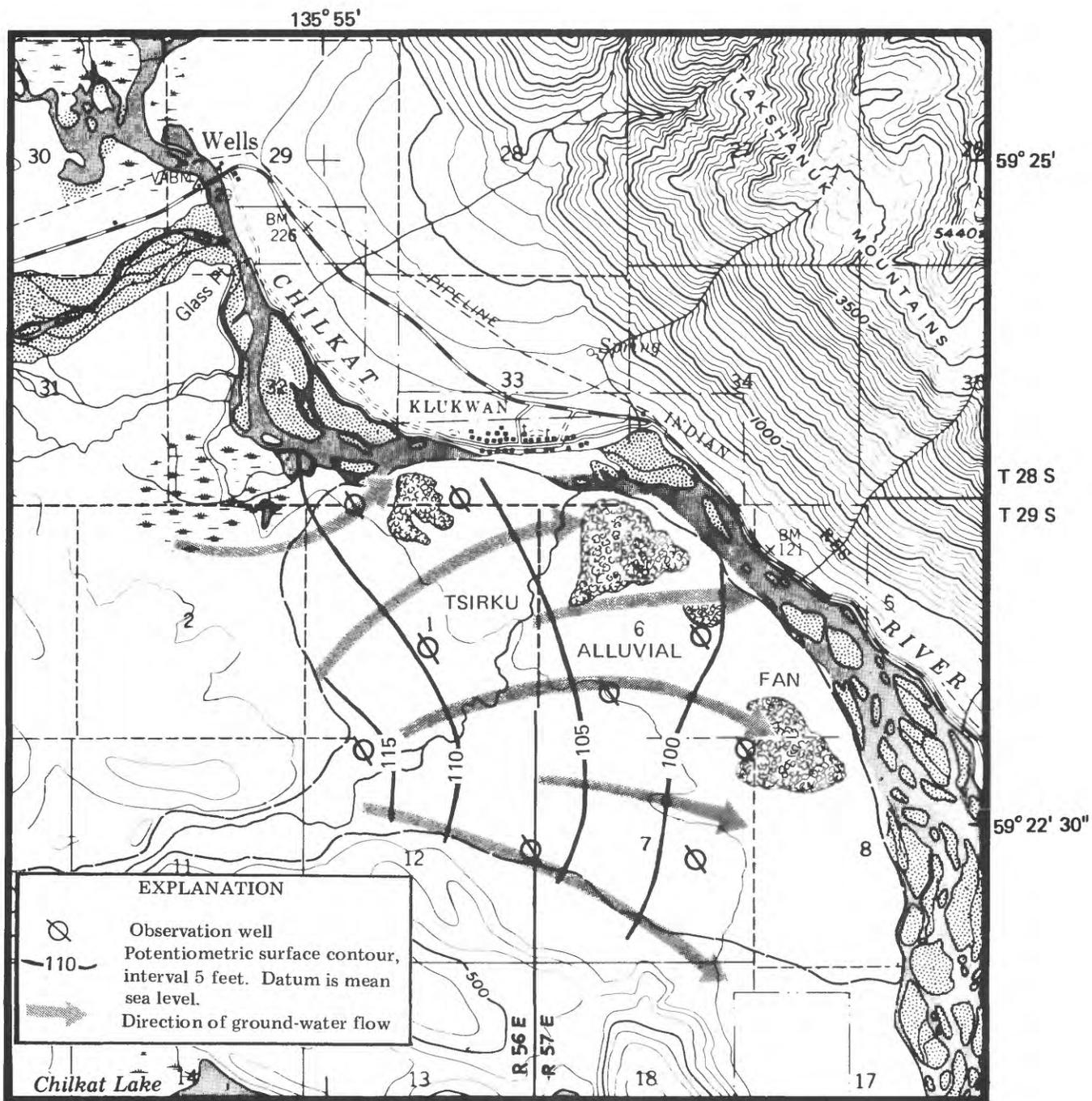
Figure 21a. -- Potentiometric surface map of shallow ground-water system and direction of ground-water movement, Tsirku alluvial fan, March 11-16, 1983.
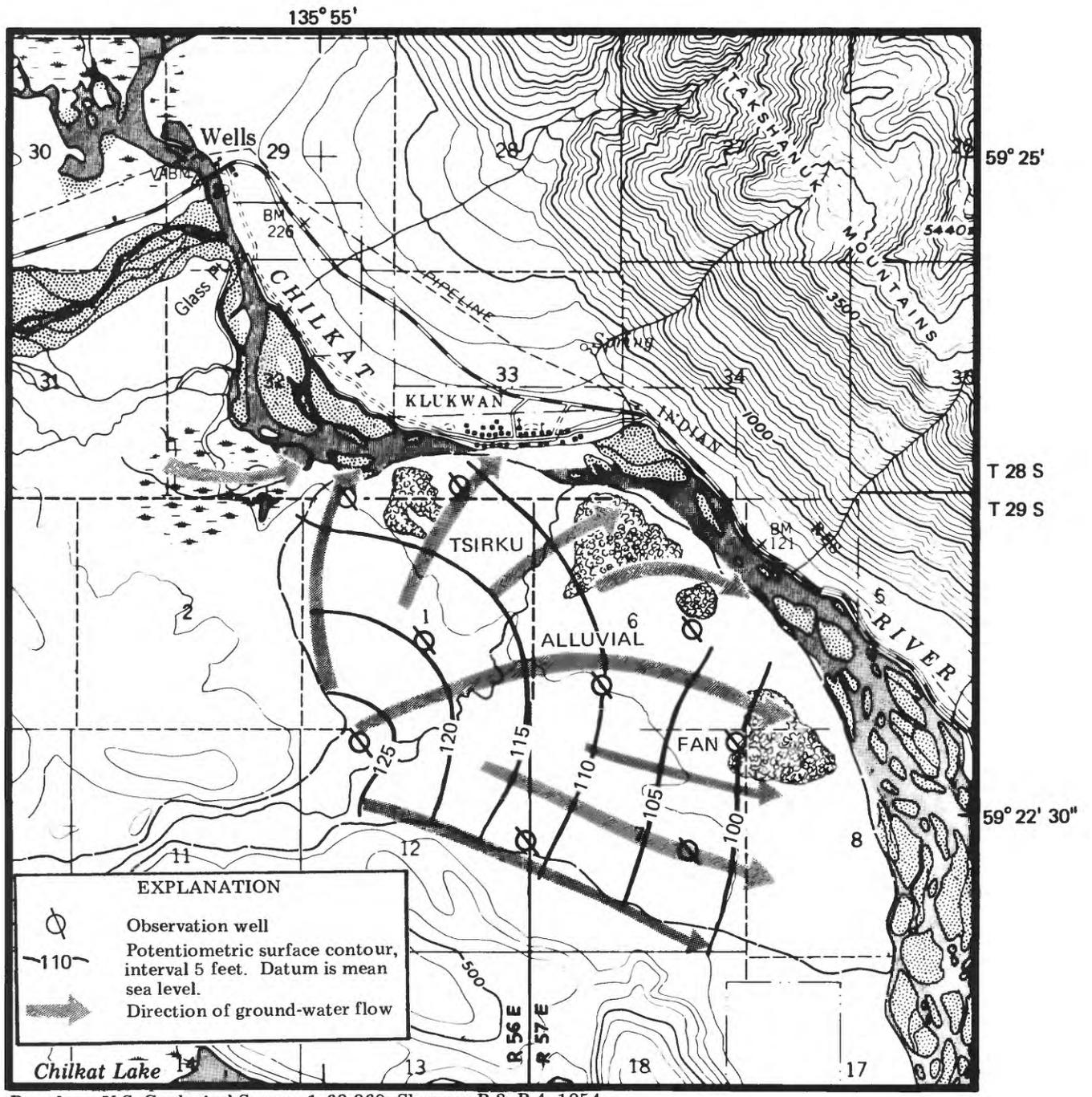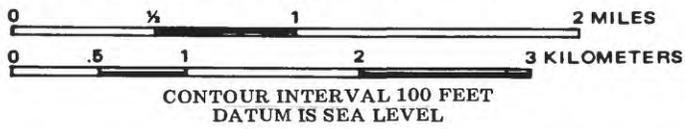
Figure 21b. -- Potentiometric surface map of shallow ground-water system and direction of ground-water movement, Tsirku alluvial fan, May 11, 1983.

Rates of ground-water flow can be calculated using the equation:

$$V = \frac{K}{\theta} i$$

where V is average linear velocity, in feet per day;
        K is hydraulic conductivity, in feet per day;
 i is hydraulic gradient, a dimensionless variable; and
        θ is porosity of aquifer, expressed as a decimal.

The hydraulic conductivity and porosity have not been determined for the Tsirku alluvial fan sediments. However, hydraulic conductivity of coarse sandy gravel is typically in the range of 200 to 2,000 ft/d. The porosity is estimated to be about 0.25, and the gradient is 0.0052. Ground water accordingly is calculated to move at rates from 4 to 40 ft/d and travel time of the water from the apex to toe of the fan ranges from approximately 0.5 to 5 years.

Stable isotopes of oxygen and hydrogen can indicate the source of precipitation that recharged the aquifer (Muir and Coplen, 1981). Precipitation at higher altitudes in inland areas is more depleted in oxygen-18 and hydrogen-2 than precipitation near the coast. Oxygen and hydrogen isotopes can also be used as tracers of ground-water movements.

The oxygen O-18/16 and hydrogen H-2/1 isotopic "signatures" of water samples from the Chilkat and Tsirku Rivers near the Tsirku alluvial fan and from shallow observation wells (AR-4, VC-1) near the Chilkat River (table 6) indicate a relatively recent water, probably from a low-altitude, near-coast source (Ivan Barnes, U.S. Geological Survey, oral commun., 1983). However, isotopic data from observation well AR-3 (260 ft) indicate a relatively older water, probably from a higher altitude, continental source (Tyler Coplen, U.S. Geological Survey, oral commun., 1983). Water from the deeper well perhaps originates in recharge areas at the headwaters of the Chilkat basin (in interior British Columbia).

Table 6.--Oxygen and hydrogen isotope data from samples collected at selected surface-water sites and observation wells

Map No. (fig. 17)	Date sampled	Well depth (feet)	Hydrogen[2]/hydrogen[1] (per mil)	Oxygen[18]/oxygen[16] (per mil)
Surface-water site				
C-1	02-10-83	--	-136.0	-18.1
C-3	12-15-82	--	-133.0	-17.4
C-8	04-08-83	--	-142.0	-18.9
S-1	04-08-83	--	-133.0	-17.8
Observation well				
AR-3	12-13-82	260	-80.0	-10.4
AR-4	12-13-82	40	-130.0	-17.2
VC-1	02-10-83	30	-131.0	-17.6

Ground-Water Discharge and Recharge

Ground-water discharge areas on gravel bars in the Chilkat River along the toe of the Tsirku alluvial fan can be easily identified by ice-free channels during the winter period (fig. 22). The relatively warm (4 to 6 °C) water keeps the channels open in the discharge areas and in a 10-mile reach below the fan. During winter, water levels in observation wells VC-1, -2, and -3 (drilled to depths of 30, 15, and 25 ft, respectively) in the gravel bars were higher than in the adjacent stream and ground-water flow into the channel was evident. During summer high flow in the Chilkat River, these gravel bars are completely inundated and the ground-water discharge zones are concealed.

Ground-water discharge in the Chilkat River at the toe of the Tsirku alluvial fan is probably caused by a downstream decrease in hydraulic conductivity and thickness of fluvial sediments, and a narrowing of the Chilkat River valley. A downvalley decrease in thickness and hydraulic conductivity of the sediments would

Figure 22. -- Part of toe of Tsirku alluvial fan, and Chilkat River on March 23, 1982. View northwest up Chilkat River valley,Takshanuk Mountains at right of photograph. Note dendritic pattern of open channels in Chilkat River where ground-water discharge at the surface keeps channels open. Klukwan is at upper left corner of photograph.

induce a damming effect, cause the potentiometric surface at the toe of the Tsirku alluvial fan to rise above the altitude of the land surface, and result in ground-water discharge. No geochemical, isotopic, or physical evidence was found to indicate that the Chilkat River fault has any influence on ground-water flow paths or discharge at the toe of the Tsirku alluvial fan.

Other areas of ground-water discharge are present in the channels of the Chilkat River both upstream and downstream from the toe of the Tsirku alluvial fan, and at several locations in the Takhin, Klehini, and Kelsall River valleys. Most of the discharge zones up- and downvalley from the Tsirku alluvial fan are seeps and springs at the bases of the alluvial and colluvial fans on the western slopes of the Takshanuk Mountains (fig. 2). This relatively warm ground water keeps the adjacent and near-downstream reaches of the Chilkat River open (ice free) during winter.

Ground water in the Tsirku alluvial fan is recharged by infiltration of streamflow from the Tsirku River, infiltration of precipitation, and ground-water inflow.

Tsirku Fan Flow System

The ground-water and surface-water flow systems of the Tsirku fan are interconnected to such a degree that development of a quantitative hydrologic budget (water in - water out) is not possible. However, data are available with which to make estimates of the relative importance of various hydrologic parameters.

The most important source of ground-water recharge to the Tsirku fan aquifer is the Tsirku River (fig. 23) and its distributary channels. From late May to early September, up to one-third of the fan's surface area is covered by numerous distributary channels (fig. 24). A seepage run conducted on April 6, 1982 (fig. 12) indicated that 63 percent (89 ft^3/s) of streamflow entering the head of the fan was lost to the fan aquifer. It was not feasible to conduct seepage runs of the fan's "summer" distributary channels. However, the April seepage run, made when the flow was confined in one channel, indicates the importance of streamflow infiltration as a recharge source.

Other sources of recharge to the Tsirku fan include precipitation and ground-water inflow. Precipitation on the 5-square-mile fan is about 21 in/yr or about 8 ft^3/s. Ground-water inflow through bedrock at the head of the fan is assumed to be negligible. Ground-water inflow through the Tsirku River alluvium at the head of the fan was calculated to be approximately 0.2 ft^3/s during winter low water-table conditions, and 3.6 ft^3/s during summer high water-table conditions.

The ground-water inflow was calculated using Darcy's law:

$$Q = KAi$$

where Q is quantity of ground-water flow, in cubic feet per day;
           K is hydraulic conductivity, in feet per day (estimated to be 1,000 ft/d);
           A is cross-sectional area of saturated zone, in square feet (winter 10,000 ft^2, summer 60,000 ft^2); and
           i is hydraulic gradient (winter 0.0016, summer 0.0052).

Figure 23. -- Tsirku alluvial fan, March 22, 1982. View southwest toward head of fan, shows single open channel extending across fan and the open channel of Chilkat River along toe of fan. Village of Klukwan is at lower right.

In summary, even if all precipitation on the fan infiltrated, it would only contribute 8 ft³/s. Peak ground-water inflow at the head of the fan is only about 4 ft³/s. However, streamflow infiltration, even measured at low flow, was 89 ft³/s. Elements of the surface-water and ground-water flow systems are shown on figure 25.

HEAT-FLOW CALCULATIONS

Heat contained in the relatively warm (average 5 °C) ground water that discharges at the toe of the alluvial fan maintains open-water leads in the winter ice cover of the Chilkat River adjacent to and downstream from the fan. If there is no significant change in the ice cover for a period of several days, then heat-flow calculations (Jobson and Keefer, 1979 and Jobson, 1980) can be simplified and used to calculate the amount of ground water that must flow into the river to maintain an observed amount of open water.

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Figure 24. -- Tsirku alluvial fan, June 6, 1981. View northeast toward toe of fan and the Takshanuk Mountains shows multiple channels on the fan, and flat terrain. The village of Klukwan is at base of Takshanuk Mountains just left of the center of the photograph.

In order to check the validity of the simplified equations, J.D. Bredehoeft (U.S. Geological Survey, written commun., 1983) calculated the amount of ground water at 5 °C that would be required to maintain the 2-mile-long, 130-foot-wide lead between Wells, near the bridge spanning the Chilkat River, and site C-7 near Klukwan. The calculations indicate that, on a cold cloudless winter night, 86 ft^3/s of ground water would balance the heat loss to the atmosphere. This value does not differ greatly from the 59 ft^3/s (fig. 12, 21 + 38 ft^3/s = 59 ft^3/s) of streamflow gain measured in this reach on April 6, 1982.

SUMMARY AND CONCLUSIONS

Flow patterns of the Chilkat, Klehini, Tsirku, and Takhin Rivers, and selected smaller streams in the Chilkat Basin are typical of streams in the northern part of southeast Alaska. Peak flows occur during the summer, glacier-melt periods, and also during high precipitation events that are common in early fall. Lowest flows occur during winter and early spring. Water is of calcium bicarbonate composition except for a small, unnamed tributary (site C-8) on the Klukwan alluvial fan, which has a calcium sulfate water.
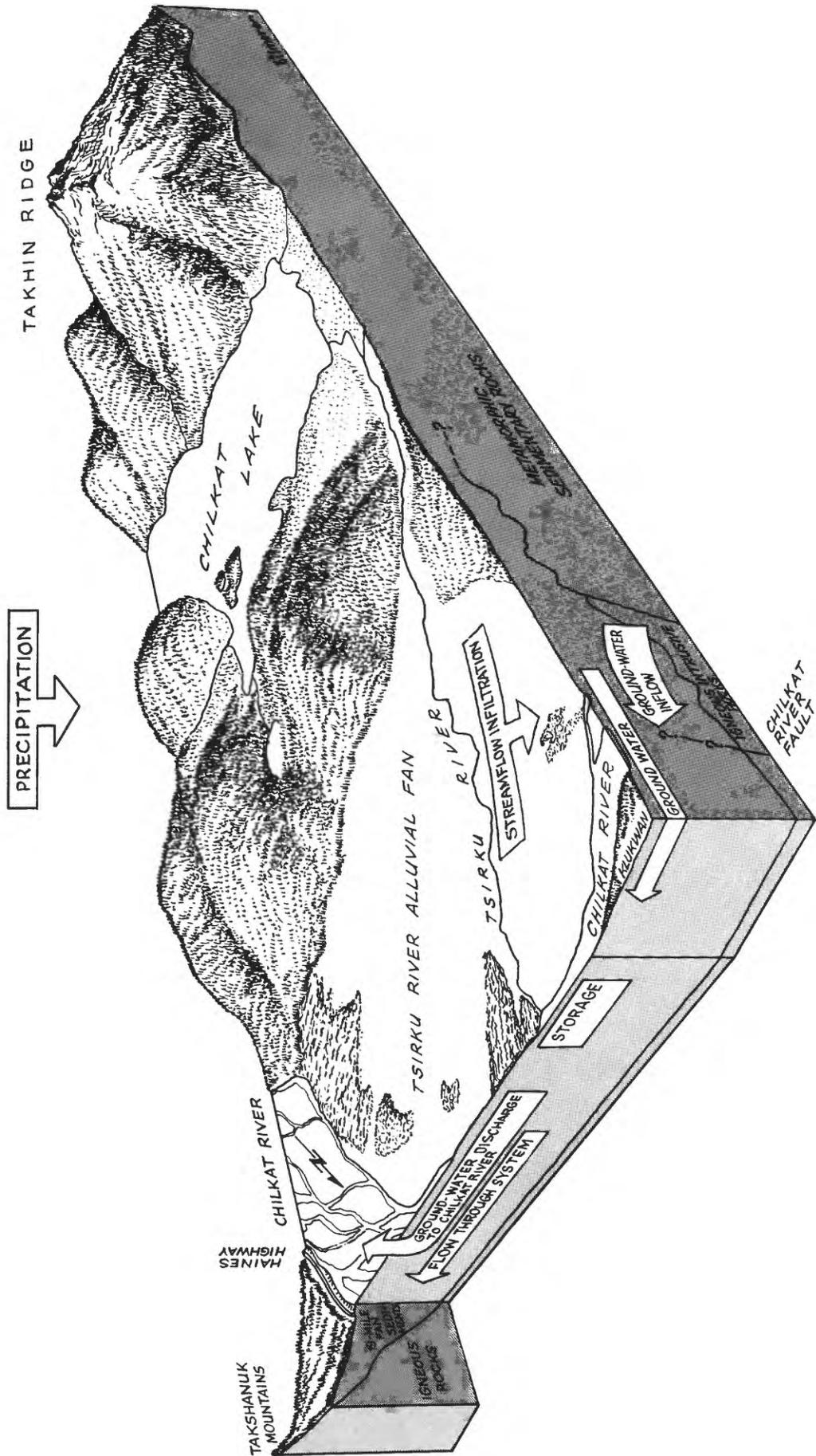
Figure 25. -- Block diagram of Tsirku River alluvial fan and vicinity, showing elements of the flow system.

Chilkat Lake was thermally stratified during the August 18, 1981 sampling and was fairly well mixed during the March 15, 1983 sampling. The mixing is assumed to be a normal occurrence. The water in Chilkat Lake is a calcium bicarbonate type as are the tributaries that feed it. At a high stage in summer 1981, the Tsirku River discharged silt-laden water into Chilkat Lake. It is not known if such an influx of suspended sediment occurs periodically or to what extent it might alter the productivity of the lake.

The ground-water and surface-water systems of the Tsirku alluvial fan are closely linked. The principal source of recharge to the ground-water system is loss of water from stream channels that cross the fan surface. Water from the unconfined aquifer discharges into the Chilkat River near the toe of the fan at about 6°C, allowing reaches of the river to remain open during winter.

During the winter the Little Salmon River and Clear Creek contribute about 81 percent of the flow of the Tsirku River at the head of the fan. The other 19 percent is outflow from Chilkat Lake.

Geochemical stable-isotope analysis of water from a deep (260 ft) observation well at the toe of the Tsirku alluvial fan suggests that water at this depth is derived from precipitation originating at high-altitude, interior locations. Shallower ground water (40-foot deep wells) is derived from a lower altitude, near-coastal enviroment.

Seismic-refraction surveys indicate that the depth to bedrock at the axis of Chilkat Valley is more than 850 ft. The survey results were confirmed by test drilling 20 ft into bedrock at the head of the Tsirku alluvial fan, and by comparison with an earlier gravimetric survey.

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